Pest Management Strategic Plan

for

Coffee Production in Hawai‘i

Summary of a workshop held on
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Executive Summary

Coffee production in Hawai‘i is diverse: farms range in size from 1 acre to 4,000-acre plantations; production practices range from organic to fully mechanized and from nonirrigated to drip irrigated; and coffee grows in widely different climatic regions throughout the state.

The coffee Pest Management Strategic Plan (PMSP) workshop was held on April 16 and 17, 2007, in Honolulu, Hawai‘i, with the participation of growers from across the state and numerous other resource people involved in some aspect of coffee production in Hawai‘i. Top pest management priorities were developed by the workshop participants. These priorities included determining research, regulatory, and educational solutions for insect pests (i.e., green scale, black twig borer, banana moth, and ants), nematodes, fungi, and weeds. Potential pests of Hawai‘i-grown coffee (i.e., little fire ant, stinging nettle caterpillar, and coffee rust) and possible control solutions and related needs were also identified and discussed.

Work Group and Contributors

A work group consisting of growers, agricultural consultants, regulators, university Extension agents and specialists, and other technical experts from Hawai‘i Island, Kaua‘i, Maui, Moloka‘i, and O‘ahu met on April 16 and 17, 2007, in Honolulu, Hawai‘i, to identify the needs of coffee growers across the state. This exercise resulted in the following document, which includes critical needs, general conclusions, and tables listing typical activities and efficacies of various management tools for specific pests.

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Top Pest Management Priorities in Hawai'i Coffee Production

(***not listed in order of importance***)

Research

- Biocontrol of green scale with the white halo fungus.
- Ant control in the green scale complex.
- Identifying nematode-resistant rootstocks.
- Identifying nematicides.
- Developing and evaluating control strategies for coffee twig borer control.
- Identifying efficacious vine control methods.
- Determining the efficacy of *Steinernema*, pheromones, egg parasitoids, and imidacloprid against the banana moth.
- Surveying of the little fire ant annually or every two years.
- Determining efficacy of registered ant baits and new baits and application methods.
- Surveying of major coffee diseases, i.e., *Cercospora*, anthracnose, and berry blotch.
- Finding efficacious new fungicides.
- Finding efficacious new pre-emergence herbicides.

Regulatory

- Registering sweet-loving ant bait (e.g., Vitus) to aid green scale control.
- Expediting registration of nematicides.
- Registering 2,4-D and over-the-top spray of Goal.
- Labeling *Bacillus thuringiensis* for use in coffee.
- Registering new baits and new application methods to control ants.
- Implementing more effective quarantine for little fire ant control intra-island and more effective inter-island quarantine measures.
- Registering identified fungicides.
- Registering additional herbicides.

Education

- Economic threshold for green scale.
- Availability of imidacloprid for green scale control; how to use.
- Best management practices (BMPs) for green scale, ants, sooty mold complex control.
- Availability of nematode-resistant rootstock.
- BMPs for nematode management and control.
- BMPs for black twig borer management and control.
- BMPs for vine management and control.
- BMPs for banana moth management and control.
- Identification of the little fire ant and BMPs for prevention.
- BMPs for disease management and control of *Cercospora*, anthracnose, and berry blotch.
- BMPs for general weed management and control.

General Production Information

Hawai‘i’s coffee industry is one of the most diverse in the world. The traditional “coffee belt” is in Kona, on Hawai‘i Island. The decline of sugarcane production in the 1980s marked the beginning of the expansion of coffee farming statewide, as many former sugarcane fields were planted with coffee. Today, in addition to growing in Kona, coffee is grown on five of the islands. The current technologies and production practices span a range of producers from one-acre, certified organic, rain-fed farms to 4,000-acre, totally mechanized, irrigated plantations. Even feral coffee is harvested from forests and long-abandoned farms on most of the inhabited Hawaiian Islands.

Coffee business operations in Hawai‘i are also quite diverse. Many small farmers sell freshly-picked cherries to large processors who sell the finished product under their label. Other small farmers partly or completely outsource the processing but then sell the processed coffee themselves under their own labels. Still other small farms are vertically-integrated, growing and processing their beans on their farms. A few small groups of growers have formed cooperatives. Finally, the largest farms (more than 150 acres) are company-owned, the result of the companies’ diversification after the decline of sugarcane profitability. These large farms are highly mechanized and completely integrated.

Coffee is grown in other parts of the world where production costs are lower than in Hawai‘i. Therefore, Hawai‘i’s growers compete not in volume or price but by producing high-quality specialty coffee. Also known as gourmet or premium coffee, specialty coffees have distinctive flavors and unique characteristics.

The only coffee species grown in Hawai‘i is Arabica, *Coffea arabica.* Arabica coffee is susceptible to most pests. Many different Arabica varieties are grown across the state. The most common include “Guatemalan” (also known as “Kona Typica”), “Red Catuai” and “Yellow Catuai,” and “Mokka.” The fragrant white flowers of Arabica coffees are self-fertile, producing red or yellow fruit called “cherries.” The variety determines the color of the cherry. Each cherry normally contains two seeds, called “beans.” After processing, the seeds are called “green beans” or “green coffee.” Coffee that will be stored for an extended time (more than a couple of months to a couple of years) is held as “parchment coffee,” which is the stage at which the parchment skin is still covering the green bean. Coffee must be stored under controlled environmental conditions (i.e., specific relative humidity and temperature); however, even under ideal conditions, quality loss is likely in “parchment coffee” stored for more than a year. Coffee is roasted just prior to sale to consumers. Only then does it have the characteristic smell and color the consumer associates with coffee.

Hawai‘i is the only state in the United States that produces coffee. (Although Puerto Rico, an unincorporated U.S. territory with commonwealth status, also produces coffee.) Commercial production in Hawai‘i has grown from 1.9 million pounds of green beans in 1992 to a high in 2005 of 6.6 million pounds with a $37.3 million farm gate value. There are about 8,000 acres in coffee production across all major Hawaiian islands.

Crop Year*	Acres Harvested	------ *Parchment Equivalents* ------		Average Farm Price	Value of sales
		Yield per Acre	Marketings		
		------ *1,000 pounds* ------			(*1,000 dollars*)
2007–2008	6,400	1.2	7,500	$4.25/lb	31,875
2006–2007	6,300	1.2	7,400	$4.30/lb	31,820
2005–2006	6,100	1.3	8,200	$4.55/lb	37,310
2004–2005	5,800	1.0	5,600	$3.55/lb	19,880
2003–2004	5,900	1.4	8,300	$2.90/lb	24,070

*Coffee harvesting occurs throughout the year in Hawai‘i. The main harvest normally begins in late summer and extends to the early part of the following year.

Worldwide, coffee is a very important commodity. In 2005–2006, world coffee production stood at about 15 billion pounds. The international price for coffee collapsed in 1998. In 2000–2001, the global traded value was approximately $5.6 billion. Total world coffee consumption is more than 6 million tons annually.

Production Regions

HAWAI‘I ISLAND (THE “BIG ISLAND”)

Kona

Most of this island’s acreage (88 percent) is in the North and South Kona Districts, home of the world-famous Kona coffee. Kona has a classic coffee climate: a dry winter (November–March) punctuated by rains (March–April), which result in flowering, and a wet summer (May–October), which is conducive to growth and development of the bean. The Kona Districts’ soil conditions, favorable temperatures, and near-optimal distribution of rainfall make this a prime area for the cultivation of coffee.

Today, the Kona Districts’ coffee farms can be found at elevations from 500 to 3,000 feet on the slopes of the Hualālai and Mauna Loa volcanoes. However, coffee fields are concentrated in an area in which production conditions are ideal: the 20-mile-long by 2-mile-wide “coffee belt,” which stretches roughly from Kailua-Kona in the north to Hōnaunau in the south. This “lower humid zone” runs almost parallel to the coastline, between approximately 700 and 2,000 feet elevation. Virtually 100 percent of Kona coffee is of the variety “Guatemalan,” also known as “Kona Typica.”

Other Hawai‘i Island Districts

The Big Island’s remaining coffee fields are scattered throughout the other seven districts, notably the Ka‘u, Puna, and Hāmākua Districts.

Coffee production began in Ka‘u in 1996 after the closing of the Ka‘u Sugar Company mill. There are 600 acres of coffee farms in Ka‘u. Most of these farms are a few acres in size and are operated by members of the Ka‘u Coffee Growers’ Cooperative. A few larger farms,

independent of the cooperative, also exist in Kaʻu. Most of the coffee grown in Kaʻu is "Kona Typica." Coffee farms in Kaʻu are not irrigated. In May 2007, after little more than a decade in production, fourteen Kaʻu farmers submitted samples to the Specialty Coffee Association of America's (SCAA) Annual Cupping Competition. That competition marked the establishment of Kaʻu's reputation as a producer of exceptional-quality coffee. In 2009, coffee from a Kaʻu farm placed seventh in the international finals of the SCAA's Roasters Guild Coffee of the Year Cupping Competition.

Puna is a region of renewed coffee production. After the end of the nineteenth century, Puna's 6,000 acres of coffee production were replaced by sugarcane. This region is warm, with high rainfall and lava rock-based soil and ranges in elevation from 1,000 to 2,500 feet. There are about 145 acres of coffee production in Puna, on 50 to 60 small farms (about 3 acres each). Sixty percent of farmers grow "Red Catuai," but production of "Kona Typica" is increasing.

Coffee production returned to Hāmākua in the mid 1990s following the end of sugarcane production in the district. This region is cool, with high rainfall and weathered red soils. In this district, coffee is grown at elevations between 350 and 2,000 feet. There are 75 acres of coffee production in Hāmākua. The average farm size is 5 to 7 acres. Farmers in this area mostly grow "Kona Typica."

In the 2006–2007 season, there were 450 acres of coffee planted to the crop in these seven districts. Most of the coffee on Hawaiʻi Island is not irrigated. Coffee grown on Hawaiʻi is hand-harvested.

KAUAʻI

Kauaʻi's acreage is predominantly planted to a variety called "Yellow Catuai." Virtually all Kauaʻi's coffee is grown on one farm, which, with more than 3,000 acres in coffee production, is perhaps the largest irrigated, mechanized coffee farm in the world. This farm is located at Eleʻele on the southwest side of the island, at an elevation of about 200 feet above sea level.

MAUI

Maui has one large, irrigated, mechanized 370-acre farm at Kāʻanapali, on the western side of the island. It is planted to four varieties, including the renowned "Mokka." This large operation is subdivided into one large farm and 20 smaller parcels. In addition, there are numerous small farms on the slopes of Haleakalā volcano that are hand-harvested. Another farm in central Maui, at the foothills of the West Maui Mountains, is part of a larger, vertically-integrated operation. Growing conditions are not uniform across the coffee farms on Maui.

MOLOKAʻI

Molokaʻi has one irrigated and mechanized 500-acre farm planted mostly to the "Red Catuai" coffee variety.

O‘AHU

O‘ahu has 170 acres on one farm on the North Shore that is irrigated and mechanically-harvested. A few small farms are located on the windward side of the island. The “Kona Typica” variety is grown.

Cultural Practices

TRADITIONAL VERSUS MECHANIZED PRODUCTION PRACTICES

Traditional Production

Coffee has been grown commercially for more than 178 years in Kona. Six- to 12-month-old seedlings are transplanted by hand from the nursery to the field. The trees are pruned by hand. Two pruning systems are practiced: the Kona style and the Beaumont-Fukunaga style, also called stump pruning. Kona-style pruning is done annually to remove the oldest of 5 to 6 verticals. The Beaumont-Fukunaga style involves removing all verticals once in 3 or 4 years, and then removing all but 3 to 5 verticals 2 to 3 months after stumping. This system results in no crop the year of pruning.

Harvesting is by hand. Because coffee fruits do not ripen evenly, a single tree will typically have fruits with different degrees of ripeness at the same time. It is quite common to see immature, mature, and overripe fruits simultaneously on a single branch. During hand-harvesting, farmers pick only ripe cherries, because these fruits produce the best flavor. Each tree is picked several times over 3 to 4 months until all ripe coffee is removed.

Hand-harvesting in Kona.
Photo courtesy Virginia Easton Smith

Mechanized Production

Mechanized coffee production is a means by which many cultural tasks are done using mechanical methods. These can include filling and seeding into paper pots, ground preparation, seeding of a temporary windbreak of Sudax® grass, laying of plastic mulch and drip irrigation tubes, transplanting, herbicide application, irrigation, fertigation, pruning, and harvesting.

For mechanized transplanting, a mechanical transplanter is attached to the back of a rubber-tire tractor. Planting is on 12 foot row spacing between rows of Sudax® grass, which is usually seeded 2 months prior to transplanting of coffee. Spacing between plants down the row is about 3 feet.

Normally, mechanical spraying is conducted in 60-day rounds to keep control of weeds. Tractor band spraying, spot spraying, and air blasting are used. Mowing is done in winter months. Large vine control can only be attempted by hand cutting the vine near the shoot-root interface and spraying the cut stump with herbicide.

Air blaster spraying for green scale. Photo courtesy Kaua‘i Coffee Company.

Removing laterals from the vertical trunk up to 3 feet from the ground is performed on farms that harvest mechanically. After hedging, all suckers emerging from the vertical trunk up to 24 inches from the ground are removed to allow catcher plates on the harvester to close around the base of the trees as the machine moves down the row. Removal of suckers by hand is not feasible in mechanical pruning systems. Farmers kill suckers that are low on the trunk using postemergence contact herbicide applications at the same time that they are controlling volunteer coffee and weed seedlings.

On Moloka‘i and Maui, coffee ripening occurs from August to January. Mechanical harvesting is done using Korvan over-row harvesters (modified blueberry harvesters). Harvesting is done 24 hours per day, 7 days per week during the peak activity period of the 3-month harvest season. On Kaua‘i and O‘ahu, coffee ripens from August to January also. If all stages of cherry maturity—green, ripe, over-ripe, and raisin (cherries that have dried on the tree)—are on the tree, the harvester removes a certain percentage of each. These percentages vary with the cultivar and the tree’s moisture status, as well as with variables in the harvesting system. Two passes can

remove all the beans (green, ripe, over-ripe, and raisin). Ripe cherries must be separated to maintain quality.*

Wastewater is generated by the factory operations. It goes through a series of settling ponds with screens and then into a freshwater reservoir where mixing occurs. After that, it is returned to the coffee field and used for irrigation.

Tree with a heavy crop of cherries at various stages of ripening.
Photo courtesy Virginia Easton Smith

Mechanical harvesting. Photo courtesy Waialua Estate Coffee

*When sprayed on coffee trees at the appropriate time and concentration, ethephon (Ethrel), which breaks down to ethylene, a natural plant hormone, will increase the percentage of ripe cherries on the tree and reduce the force necessary to knock off ripe cherries. Ethephon is not yet registered for coffee production in the United States.

ORGANIC PRODUCTION PRACTICES

Organic methods use the same pruning and harvesting systems as in Kona but do not use certain fertilizers or pesticides.

Harvesting is by hand. There is an increasing number of organic coffee farms that follow the same general schedule used in traditional production.

Weed control. String trimmers and mowers are used on organic as well as some conventional farms. Hand-cutting and spraying the cut stump with an organically-approved herbicide are the only tactics that can be used against large vines. Geese and chickens, either confined or loose, are used to manage weeds on organic farms.

Integrated Pest Management

Integrated pest management in Hawai‘i coffee production targets the most significant insect pests: green scale (*Coccus viridis*), black twig borer (*Xylosandrus compactus*)*,* and ants (various species). Banana moth (*Opogona sacchari*) is a recent and sporadic pest of coffee, and limited IPM efforts have been implemented to date. There are few insecticides registered for use in Hawai‘i coffee production, and biological and cultural pest suppression techniques are often used. There is no formal IPM verification program for coffee production in Hawai‘i.

Green scale IPM is facilitated by an entomopathogenic fungi (*Verticillium lecanii*), which may cause high levels of mortality at cooler times of year, particularly in the Kona coffee-growing areas. Parasitoids and predators have also been shown to play a role in green scale suppression. Imidacloprid has been registered for green scale control in Hawai‘i and is applied by some growers, either as a foliar spray or root drench, depending on formulation. (See Appendix 1 for an economic threshold for green scale.) Big-headed ant (*Pheidole megacephala*), longlegged ant *(Anoplolepis gracilipes*)*,*[*] and white-footed ant (*Technomyrmex albipes*) are the most common ants found farming green scale and protecting them from natural enemies in coffee orchards. Ants feed on the honeydew secreted by green scale. This feeding can cause an increase in the populations of ants, which then farm the scales with more intensity. The resulting abundance of honeydew cannot all be consumed by the ants, and sooty mold develops on the excess honeydew. Copper fungicides can control sooty mold, but green scales (and ants) should be controlled initially. Furthermore, copper fungicides may kill the beneficial *V. lecanii,* which infects green scales, so it might be harmful to use copper for disease control. Ant control must be undertaken judiciously, because elimination of one ant species results in other ant species replacing the first as the dominant ant species. There are no chemical controls for sweet- and protein-loving ants.

Black twig borer management continues to be based on pruning and destruction of infested material. Current work is investigating the pest status of this insect, trapping for monitoring and control, and utilizing chemical control and cultural options. Trapping using Japanese beetle traps baited with ethanol has been shown to be an effective means of sampling adult beetles. The influence of different shade trees and border species is being investigated to determine which enhance or reduce black twig borer populations in the coffee crop. Predatory beetles attacking

[*] The longlegged ant is also known by the older species name, *Anoplolepis longipes.*

black twig borer larvae have been recorded in the Kona area, and the potential to use these species in augmentative biological control programs is under consideration.

Banana moth has been found to inflict high levels of damage to young shoots on recently-pruned coffee at higher elevations in Kona. Entomopathogenic nematodes have been tested in small trials for control of this moth, with encouraging results. Current work on this insect in coffee is investigating the use of pheromones for moth monitoring and the role of natural enemies as egg parasitoids.

Crop Stages

SITE PREPARATION (ESTABLISHMENT)

Compliance with NRCS Requirements (Farm Conservation Plan)

Land is cleared of heavy vegetation and large rocks prior to planting coffee. After the vegetation has been cleared, the area is mapped. A soil conservation plan is produced in compliance with the USDA Natural Resources Conservation Service (NRCS). Maps include the contours of the land, tree spacing, windbreak locations, and approach roads to allow vehicles to enter and traverse the orchard.

Development of Best Management Practices

Nematode management. A serious disease of coffee has occurred in the Kona region in recent years, characterized by individual or clustered poorly-growing or stunted coffee trees. Initially, it was referred to as "transplanting decline," "replant problem," "nutritional stress," and "Kona wilt." Plant pathologists at the College of Tropical Agriculture and Human Resources (CTAHR), University of Hawai'i at Mānoa, have determined that it is caused by a new species of root-knot nematode, named *Meloidogyne konaensis*.

Farm soils are assayed for nematodes. If present, the nematodes are identified, and growers must consider the full range of management options. These options include the use of grafted plants on "Fukunaga" rootstock, which is tolerant of nematodes; weed control; nutrition and water management; organic soil amendments; and growing coffee under shade.

Keep farms nematode free. The Kona coffee root-knot nematode has created a need to follow sanitary practices in transplanting

Installation of Windbreaks

Well-established windbreaks are necessary at farm sites exposed to trade winds or severe "Kona" storms. In windy areas, the installation of temporary windbreaks is essential prior to transplanting. Rows of Sudax® grass, a sterile hybrid of sorghum and sudan grass, should be planted, usually 2 months (at least 6 weeks) prior to transplanting coffee.

When coffee trees are young, protection had been provided by the tall, narrow, fast-growing "Tropic Coral" wiliwili (*Erythrina variegata*), planted 3 to 4 feet apart in rows 100 to 150 feet apart. However, a newly introduced pest, the erythrina gall wasp (*Quadrastichus erythrinae*) has caused defoliation and death of most of these wiliwili trees. Some growers have been replacing devastated wiliwili windbreaks with panax (*Polyscias guilfoylei)*. As the orchard matures, it is protected by taller trees such as Norfolk Island pine *(Araucaria heterophylla)* or a nonspreading

type of ironwood (*Casurina cunninghamiana*), planted 6 to 8 feet apart in rows 600 to 800 feet apart.

PREPLANT (IN THE NURSERY)

Seedlings for transplanting should be raised in nematode-free media in sufficiently large bags or open-ended tubes to prevent spiraling of the roots, called J-root. The University of Hawai‘i’s nematode-resistant rootstock “Fukunaga” can be purchased as graftable plants, or grafted with a preferred variety, from www.konacoffeenursery.com.

TRANSPLANTING

Coffee orchards are started from transplants. Coffee seeds are rarely planted directly into the orchard, primarily because they germinate slowly and weeds become a problem. For most situations, purchasing ready-to-plant seedlings is the most cost-effective alternative. Lime and phosophorus amendments, if needed, are applied prior to transplanting.

In Kona, transplanting is done during the beginning of the rainy wet season, preferably early April through July, but may be done as late as September. Where fields are irrigated, transplanting may be done at any time during the year.

At windy sites, an infield windbreak, such as Sudax® grass or Sunn Hemp, is used to protect transplants. Alternatively, bamboo support stakes are used. Films and woven black plastic ground covers are used in the plant rows prior to planting and are left in place to degrade over time.

Transplanted seedlings are from 8 to 10 inches tall (20 to 25 centimeters) or 6 to 9 months old. Taller seedlings can compete better and will bear earlier, but they will be more expensive because they may spend 12 to 14 months in pots. More time in the pot also increases the likelihood of J-root formation.

Growers are advised that the stems of coffee seedlings should not be transplanted so deeply that the first lateral root to emerge is very deeply buried. Rather, the first lateral root should be at or near the soil surface. Transplant holes are prepared in such a way as to prevent plants from sinking into the hole after transplanting. Where coffee plant stems are too deep in very moist or heavy soils, basal stem rot, bark rot, and stem girdling can occur, resulting in possible plant wilting, dieback, or death. Transplants should be irrigated but not kept overly wet. Very wet soils favor the development of pathogens such as *Rhizoctonia* and *Pythium* spp. that can cause root rot. Some growers clip off J-roots from seedlings before transplant, but such a practice can destroy the taproot and predispose young plants to lodging during strong winds. Some growers choose to till or rip the soils significantly before planting and also practice pre- or post-plant weed control to enable adequate rooting of young coffee plants.

In Kona, trees are planted on 8-foot row spacing with 8 feet between rows (680 trees per acre). On large farms, a mechanical transplanter attached to the back of a rubber-tire tractor is used. On Kaua‘i, planting is on 12-foot row spacing between rows of Sudax® grass. (Sudax is planted usually 2 months prior to transplanting). Plant spacing within the row is about 3 feet. On O‘ahu, between-row spacing is 10 to 12 feet (1,210 to 1,452 trees per acre).

The recent appearance of the Kona coffee root-knot nematode (*Meloidogyne konaensis*) has created a need to follow sanitary practices in transplanting. Nematodes can be transported in the roots of volunteer coffee seedlings (*pulapula*) if these are moved to new planting sites. This should not be done unless the soil of the orchard they are taken from has been assayed and declared free of the nematode. When seedlings are grown in containers in media that includes soil, this also should be analyzed for the presence of nematodes.

Coffee intended for planting in an old or existing coffee orchard in Kona should be grafted onto rootstock of the species *Coffea liberica* var. *dewevrei*, known as "Fukunaga," if the soil assay finds the Kona coffee root-knot nematode.

THE YOUNG COFFEE ORCHARD

The most critical period in the life of a coffee orchard is the first five years. During this period, the trees must be fertilized, protected from pests, and pruned for efficient growth and future production. Broadcast fertilizer—conventional or organic—is applied several times during the year and in increasing amounts as the trees age and begin producing commercial yields.

Vigorous weed control is essential in the first 12 months to insure the crop is established. Currently, artificial mulches are most often used as barriers to weed growth. Two common types are black plastic film and black woven cloth ("weed cloth") that is permeable to water. Normally, weed cloth is laid before transplanting to keep weeds away from the area where the feeding roots are most numerous. During the dry season, mulch helps maintain soil moisture, which is particularly important at lower elevations. Hoeing or hand-weeding is expensive, and mulches are a good way to minimize the expense of weed control during the first year.

Harvesting begins at year three. By year five, trees should be bearing a commercial yield, and a target of 10,000 pounds of cherry per acre is feasible.

MAINTENANCE

Irrigating

Many farmers in the Kona coffee belt or in areas where annual rainfall exceeds 60 inches per year do not irrigate. However, irrigating in areas with less than 40 inches of rain is essential, particularly between fruit set and harvest. Irrigation at flowering is essential to avoid aborting flowers. Irrigation is also essential at 17 weeks after flowering to reduce fruit abortion and increase bean size and filling of beans.

Research in Hawai‘i has shown that young, nonbearing coffee trees require 60 percent of the amount of water normally lost to evaporation from an open pan, whereas bearing trees that are more than 2 years old demand 75 to 80 percent of pan evaporation. Optimal irrigation is 80 percent of net evaporation (weekly open-pan evaporation minus weekly rainfall) with adjustment for ground cover.

The amount and frequency of irrigation are important considerations. The correct applications depend on a number of factors, including environmental variables such as exposure to sunlight, air temperature, elevation, weeds, soil type and condition, and coffee variety or rootstock.

It is important not to overirrigate coffee plants. Overirrigation is more likely to occur on heavy clay soils, which hold more water and drain slowly. However, overirrigation can occur on *a'ā* lava soils if there is a solid rock "pan" below the surface that allows water to stand.

Overirrigating can lead to waterlogged conditions resulting in poor root development, root injury, poor yields, and—if uncorrected—death of the plants. Symptoms of extreme overirrigation may include some wilting, and frequently, leaves may have dead margins. Later, laterals and the top of the vertical die, with the dead leaves remaining on the tree. The symptoms may appear to be damage from black twig borer, but this cause can be eliminated if no entry holes into or near the affected stems are found.

Irrigation emitters should be gradually moved away from the stems of transplants in the weeks and months after planting. This encourages more vigorous root growth by stimulating the roots to grow toward the water.

Irrigation is used year-round except during wet weather. Kaua'i production uses drip irrigation with sand filtration and chlorination to keep drip emitters from clogging.

Fertilizing/Amendments

Lime and phosophorus amendments, if needed, are applied prior to transplanting. Broadcast fertilizer—conventional or organic—is applied several times a year and in increasing amounts as the trees age and begin producing commercial yields.

On Kaua'i, fertigation is applied monthly all year long until 1 month before harvest. (The last application usually occurs in August.) Potash amounts are increased as cherries fill out. Then liquid nitrogen, phosphorous, potassium, and calcium are applied. Postharvest, one round of nitrogen and potassium is applied in December. In newly-pruned fields, growers apply bands of gypsum or dry calcium carbonate in the spring. For growers who use it, fertigation has become their highest cost. On O'ahu, the total annual fertilizer requirements are 300 pounds of nitrogen per acre, 100 pounds of phosphorous (P_2O_5) per acre, 500 pounds of potassium (K_2O) per acre, and calcium, magnesium, zinc, and iron, based on the results of soil analysis. Either drip or granular applications are used.

Weed Control

To obtain good coffee yields, weeds must be controlled regardless of the pruning system, degree of mechanization, or fertilization program. Among the important weeds affecting coffee are vines such as morningglory, ivy gourd, bittermelon, and maile pilau, to mention a few. Volunteer coffee seedlings are a particular problem in mechanically-harvested orchards. Vigorous weed control is essential in the first 12 months to insure the crop is established.

Chemical control. Roundup, Goal, Fusilade, and Gramoxone are used on conventional farms.

Mechanical control. String trimmers and mowers are used on conventional and organic farms. Hand-cutting large vines and spraying the cut stump with herbicide are the only tactics that can be used against them.

Biological control. Geese and chickens, confined or loose, are used by organic farms.

Ground covers and cover crops. An important benefit of cover crops is that they allow the reduction or elimination of weed control measures, including herbicide applications. Properly selected cover crop species can establish effective soil cover and minimize soil surface exposure, providing protection against soil loss on highly erodible lands and contributing to the control of weed infestation. Planting a cover crop produces a uniform ground cover that is more efficient to mow than a mixed, volunteer ground cover. Even so, allowing volunteer ground covers and

keeping them mowed is a common practice that works well when there are no vines to become tangled in the mower or to climb the coffee trees. Research to evaluate cover crop species in coffee is ongoing.

Insect and Disease Control

Mechanized coffee-growing operations control green scale with crop oil, imidacloprid, and copper hydroxide using air blast sprayers. An economic threshold formula (see Appendix 1) is used to determine when and where to apply insecticides against green scale. Insecticides and fungicides are not applied where white halo fungus is effectively controlling the scale, which usually occurs in the wetter areas and in wet months. Usually, insecticides and fungicides are applied as needed from February to August for scale and sooty mold.

Rat Control

Farmers use enclosed bait stations on the perimeter of the orchard.

Mulching/Mowing

In general, mowers can be used to mulch debris that remains from pruning or other activities. Rotary mowers are used to control weed or cover crop growth in walkways.

At the large, vertically-integrated operation on Kaua‘i, coffee pulp and parchment are allowed to remain in compost piles for a few years and then are spread in newly-planted or pruned fields. A problem with this method is that vine seeds may survive composting and subsequently germinate in the field.

Some farms on the Big Island regularly mow to keep the weeds down.

Composting

Growers return waste cherries to the field.

Pruning

Coffee is a small evergreen tree that flowers on the previous year’s growth. Left unattended, an Arabica coffee tree can grow to be 30 feet tall with a central stem. The tree has two distinct types of branches: *vertical* (orthotropic) and *lateral* (plagiotropic). The basic difference between vertical and lateral branches is growth habit. Verticals always grow upward. They produce laterals once at the leaf nodes, and thereafter they produce only new verticals at those nodes. Laterals grow horizontally and produce leaves, flowers, and new laterals (sublaterals) at nodes, in this order. As the unpruned coffee tree gets older, the main vertical becomes surrounded by a mass of intertwined and crossed sublateral branches.

Flowering and fruiting occur at the nodes of the laterals and rarely on the verticals. Under normal conditions, flowers are produced only once at each node. The new growth on laterals is called growing wood. Fruit clusters appear at the nodes of this new growth during its second year, when it becomes known as bearing wood. While fruit is maturing on the bearing wood, new growing wood for the next crop is being produced at the end of the lateral. The size of the next crop depends upon how much growing wood is produced during any given year, or, more precisely, on the number of new nodes on laterals.

Because the growing wood is being produced while the fruit is maturing, the tree is taxed for nutrition simultaneously by the growing wood and the developing fruit. As a result, when the tree is overloaded with fruit, very little growing wood is produced. Because the next year’s crop

is produced on this year's growing wood, overbearing during one year results in a small crop the next year. On the other hand, if the crop is small this year and the tree is able to produce more growing wood, the result will be a larger crop next year. Thus, the normal tendency of coffee is to bear a heavy crop one year and a light crop the following year.

Careful pruning of coffee trees is one of the most important cultural practices. Improper pruning can reduce yield and subject trees to biennial bearing, often resulting in dieback, in which leaves, fruit, laterals, and sometimes verticals die before harvest due to exhaustion of nutrients (particularly nitrogen) and depletion of carbohydrates in the tree due to overproduction of fruit. The farmer must prune correctly for efficient annual production and healthy trees.

The principle objectives of pruning are (1) to control biennial bearing through control of flowering and fruit setting, (2) to regulate the age of the bearing portion of the tree by training and shaping it into a predetermined form or pattern, and (3) thereafter to maintain the tree in a young and productive condition. Pruning also facilitates farmers' management activities, such as harvesting.

Pruning is most profitably and effectively done from just after harvesting through the semi-dormant period, which occurs January through March. This holds for all of Hawai'i's coffee areas, as the tree is semidormant due to the cooler temperatures and shorter daylengths of the winter months.

When the harvesting season continues throughout the year, as in upper elevation (cooler), rainy areas, where seasonal changes do not affect regular seasonal characteristics in flowering and fruiting, it may be necessary to prune at various times. Under these conditions, old verticals may be removed by sawing through them partially and bending them over without completely severing them. The sawing should be done just before a round of harvesting. This allows the cherries on the partially severed verticals to mature while new verticals develop just below the point of sawing. After the cherries on the cut verticals have matured and been harvested, the verticals may be completely severed and removed from the tree.

Kona Style. "Kona style" pruning, the most popular pruning style in Kona, is a multiple-age vertical system. If it is done properly, in addition to maximizing the health and productivity of the trees, pruning admits light to various parts of the tree. This encourages the type of growth and fruiting that permits easiest hand-harvesting with the least reduction of yield. It also encourages the production of a uniform, high-grade coffee cherry, and it facilitates the effective control of insects. On the negative side, annual hand pruning is required, and a good understanding of the system is essential to select the appropriate verticals for removal. This system cannot be mechanized except by using chain saws and power loppers instead of hand tools.

Beaumont-Fukunaga Style (also known as "stumping"). Instead of renewing one or two verticals in each successive year as in the "Kona style," all the verticals on the tree are renewed in the same year every 3 to 5 years. All verticals on the trunk are removed at one time. In other words, the tree is cut (stumped) 18 to 24 inches above the ground, usually with a chain saw. This height is for ease of desuckering and harvesting by hand.

In mechanical operations, fast-growing varieties, and in fields where there is little scale damage, trees are stump-pruned at 30 inches high. If the trees are mechanically-harvested, the cut should be above the height of the catching pans to reduce dropped fruit. On O'ahu, alternate rows are stumped on a rotational basis. Hedgerow plantings are stumped every 4 to 7 years in a blockwise fashion.

CTAHR Hedging and Topping (HAT) Style. This pruning style is primarily for mechanical harvesting or for when sufficient labor is either lacking or too expensive. These operations also do mechanical skirt pruning as well as sucker pruning using paraquat.

Pruning can be done after harvest, up until May. Decisions regarding in which year to prune are based on the tree size and expected yield. Pruning is done if trees are too tall or wide to easily harvest or to perform other cultural activities and if the crop will be small. The hedging stimulates the regrowth of sublaterals. The topping brings light into the center of the tree, resulting in the production of new verticals on remaining old verticals, particularly at the top near the cut. New primary laterals will be produced on these new verticals. In summer, the tree should be topped again near the first topping to further encourage production of new sublaterals. Yield in this year will be small in most cases. Most of Kaua‘i’s fields are hedged at 5 feet.

Suckering

It is important to remove unwanted young verticals, called “suckers,” that the farmer does not wish to develop into bearing verticals. This can be done when the suckers are 3 to 6 inches in length, at which time they can easily be pulled off. When they are smaller they can simply be rubbed off with the palm of the hand. In Kona these unwanted branches grow most prolifically during the rainy months of April to August. The usual practice is to remove them every other month during this period. This is a must for the “Kona style” pruning, but it is usually not necessary in hand-pruned Beaumont-Fukunaga systems after the first year.

Removal by hand is not feasible in mechanical pruning systems. Suckers low on the trunk are killed by postemergence contact herbicide applications (e.g., paraquat) at the same time that volunteer coffee and weed seedlings are controlled. On mechanically-harvested farms, all old suckers emerging from the ground and up to 24 inches on the trunk are removed by hand or by herbicide sprays to allow the catcher plates on the harvester to close around the trunk of the tree as it moves down the row.

Tree skirting

Removing laterals up to 3 feet from the ground level is performed on farms that use mechanical harvesting.

REPLANTING

Kona growers have some coffee trees that are said to be more than 100 years old. Therefore, it seems that well-maintained coffee trees can survive for many years. It is not known if there is a significant decline in yields as trees age. In general, individual trees are only replaced when a tree dies, or in the case of large growers, when there is a switch to a different variety. However, replanting is necessary if too many trees die. In Kona, some replanting has been necessary, because root-knot nematode infestations have caused large numbers of tree deaths. Other causes of large numbers of tree deaths are overbearing dieback, waterlogging, or mechanical damage.

FLOWERING

Below an elevation of 1,600 feet, coffee flowers between January and April. Flowering can occur year-round at elevations above 2,000 feet.

Pollinating

Arabica coffee flowers are 80 to 90 percent self-pollinated, so bees are not essential. Coffee pollen is heavy and sticky and is picked up and carried by bees when they visit flowers for nectar. Bee pollination may result in larger seeds and fewer peaberries (a defect that is marketed, paradoxically, as high value grade).

RIPENING

Fruits take 6 to 8 months to ripen. In the lower part of the Kona coffee belt, coffee ripens from late August to December. On Kauaʻi, Molokaʻi, Maui, and Oʻahu, coffee ripening occurs from August to January.

HARVEST

Coffee harvesting occurs throughout the year in Hawaiʻi. The main harvest normally begins in late summer and extends to the early part of the following year. The period from late September to early November is the busiest. By contrast, in the extreme upper (cooler), wet, and cloudy section of Kona, the harvesting period can stretch throughout the year. On Kauaʻi, Molokaʻi, Maui, and Oʻahu, coffee ripening occurs from August to January.

Large coffee farms in Hawaiʻi harvest mechanically. Labor is expensive, and agricultural workers are scarce. Mechanical harvesting is done using Korvan over-row harvesters (modified blueberry harvesters). Harvesting is done 24 hours per day, 7 days per week during the peak activity period of the 3-month harvest season.

Mechanical harvesting. Photo courtesy Waialua Estate Coffee.

POSTHARVEST (PROCESSING)

Cherries are processed as soon as possible after harvesting to avoid deterioration of the bean. Before pulping, flotation of the cherries is recommended in order to separate immature, dried, and overripe cherries. These will float, while the better-quality ripe berries will sink. The floaters are pulped separately.

Coffee fruit have an outer skin, with pulpy flesh underneath. Beneath the pulpy flesh is a layer of slimy, mucilaginous matter, and beneath that is the parchment skin, a very tough, almost shell-like coating that is difficult to remove. After being harvested, cherries are pulped, either by natural fermentation during soaking or by mechanical means. The mucilaginous layer is removed after the beans have been pulped. The coffee beans are then dried, and after that they are ready for milling. At this point, they are still covered with their parchment skin and are referred to as "parchment coffee." Parchment coffee is a stable, dry, hard seed that is protected from pests and diseases. It is ready for transport and storage.

Beneath the parchment skin, a thin membrane called the "silver skin" covers the coffee bean. A small portion of this skin is usually found on the cleft of the bean after it is hulled. After hulling, the bean is referred to as "green coffee."

There are two distinct processing methods, dry and wet, and both methods are used in Hawai‘i.

Wet Process

The wet method is used throughout the state and particularly in Kona. It involves the removal of the pulp, fermentation of the mucilaginous material covering the parchment skin, rinsing, and then drying by the sun or a mechanical dryer.

Fermentation and wash water disposal. The fermentation and wash water often remains on site and is reused to irrigate farms.

However, this water requires processing before it can be reused. At large operations, wash water goes through a series of settling ponds with screens and then into a fresh water reservoir where mixing occurs. It is then ready to be used to irrigate the farm.

Dry Process

The dry method is used at a few of the small farms in Kona and at the more recently established large coffee operations. It is used on raisins (cherries that have dried on the tree) or fresh cherries, which are dried whole without pulping or fermentation. On O‘ahu, cherries are predried on a slab and then dried by the sun or a mechanical dryer to 11 percent moisture. After being thoroughly dried, the cherries are milled to remove the dehydrated pulp, parchment skin, and silver skin in one operation. The resulting product is green coffee, ready for grading and bagging.

Mechanical Demucilaging

The wet process, while efficient at removing mucilage, results in large quantities of dirty water that must undergo a great deal of purification before it can be reused. For the dry process, fruits are left on the trees until they are past their prime, increasing the chance that the coffee will spoil or be wasted because of falling from the trees. A solution to the wastewater problems of the wet process is mechanical demucilaging. In mechanical demucilaging, after pulping, the seeds are sent through a machine that rubs mucilage off the seeds. Mechanical demucilaging technology has improved, and now the amount of water used is less than 5 percent of that used in traditional wet fermentation. After the seeds are rinsed with minimal amounts of water they are ready for drying.

DRYING

As soon as the beans are demucilaged and washed, they are dried either by the sun or in mechanical dryers. A combination of the two is most popular.

Sun Drying

On small coffee farms in Kona, drying is often done on platforms called *hoshidanas*. The beans are spread evenly over the drying area and turned over periodically. Provision is made to protect the beans from rain, usually with movable roofs over the platforms. Operations in the newer coffee-growing areas of Hawai‘i use fixed or movable clear plastic roofs or tunnels with fans for ventilation. In Kona, it takes from 4 to 6 days to completely dry coffee beans when sunny weather prevails. If the weather is cloudy, it takes much longer. The thickness of the layer of beans on the drying area also affects drying time. A layer 1 to 1½ inches deep should be turned three to four times a day.

In Puna, beans are dried in open-air hothouses at 100ºF. Dehumidifiers are used in the hothouses during periods of heavy rain.

Mechanical Drying

The use of mechanical dryers is becoming increasingly popular. The beans can be placed in the dryer right after washing. Alternatively, sun-drying and artificial drying can be combined, first drying the beans on a drying floor for 24 to 48 hours or longer, then finishing them in the mechanical dryer. The temperature and air volume are very important factors. The most important principle in artificial drying is that heat should be introduced at a low temperature at first and gradually increased, particularly if an early model of rotary dryer is used. When possible, beans are sun-dried for a day before being put in a dryer. If that is not possible, a starting temperature of 95°F is used in the dryer, and the temperature is gradually raised to 140°F. Overheating ruins the quality of the coffee.

Pest Pressures and Control Measures

The remainder of this document is a pest-by-pest analysis of pest management in coffee production in Hawai‘i. Key management practices and their alternatives (current and potential) are discussed. Differences between production regions within and throughout the islands are discussed where appropriate. Pests are ordered, roughly, by economic importance, with the pests causing the most economic damage listed first.

Invertebrate Pests

Green scale (*Coccus viridis*)

Green scales suck sap from the coffee plant and excrete a sweet substance, called honeydew, which covers the leaves and supports the growth of "sooty mold." Sooty mold fungus does not infect the leaf, but it blocks sunlight, reducing photosynthesis. Honeydew also attracts certain species of ants. The ants harvest the honeydew for food and protect the scales from their natural enemies. Heavy scale infestations can kill young trees, weaken and stunt mature trees, and reduce coffee bean grade (bean size) and yield. Fields require frequent monitoring for and control of green scale when trees are young and after pruning, when new growth appears. An economic threshold for green scale has been developed and should be followed (see Appendix 1). Green scale is a year-round problem, but it can be particularly serious during dry seasons and in dry areas (e.g., west Kaua‘i).

The beneficial white halo fungus (*Verticillium lecanii*) infects green scales. Growers report that they do not apply pesticides when white halo fungus is effectively controlling green scale.

Sooty mold complex (*Cladosporium* spp.)

Sooty mold grows on leaves and stems on the surface of the honeydew produced by green scales. Although sooty mold does not infect the coffee plant, it reduces photosynthesis by directly blocking sunlight to leaves and green stems. This weakens the plant and increases its susceptibility to other pests. Sooty mold may contribute to yield reduction if it is left unchecked. If it covers the cherries, it may lengthen the ripening period. By controlling green scales, sooty mold is controlled. Copper fungicides can control sooty mold, but green scales (and ants) should be controlled initially. Furthermore, copper fungicides may kill the beneficial white halo fungus that infects green scales, so it might be harmful to use copper to control sooty mold.

Chemical control:
(*Note*: only the chemical controls that are actually used are specifically discussed below. For all insecticides labeled for use on coffee in Hawai‘i, see Appendix 4.)

- Imidacloprid (Provado, Admire Pro)
  Imidacloprid is effective against green scale, and Provado appears to have some residual activity. Admire Pro is systemic, while Provado is translaminar (i.e., it moves through the leaf tissue to protect the untreated side of the leaf). Imidacloprid is a low-risk

replacement for organophosphates and carbamates (good for IPM). Admire Pro has fewer nontarget impacts than Provado. Imidacloprid might also suppress black twig borer.

Imidacloprid products are expensive. Provado is toxic to honey bees, and Admire Pro has the potential to contaminate groundwater. There is potential for resistance development, and neither formulation is certified organic.

- Pyrethrins (Pyganic)

  Pyganic is certified organic and effective in controlling this pest complex. It has short residual activity and therefore fewer effects on beneficials.

  Pyrethrins do kill beneficials, and the products are expensive. They do not control adult green scales. Pyrethrins have very short residual activity if they are applied in full sun. (They photodegrade very quickly, in 10 minutes.)
- Piperonyl butoxide + pyrethrins (Pyronyl)

  Can be good for resistance management. It has short residual activity and therefore has fewer effects on beneficials.

  This product is not certified organic. Like Pyganic, it will kill beneficials. It is expensive and will not control adult green scales. This combination has a short residual because of photodegradation.
- Potassium salts of fatty acids (insecticidal soap) (M-Pede)

  Certified organic, has few nontarget impacts on beneficials, and seems to be more effective when mixed with oil.

  Difficult to obtain full coverage for good efficacy. Must be applied properly and repeatedly and can be phytotoxic. It is expensive to use mainly because it has short (no) residual activity and therefore requires repeated applications.
- Hydramethylnon (Amdro Pro)

  Good efficacy against oil-loving ants that farm green scales. Can be broadcast in the nursery and in stumped fields. Becomes ineffective with rain and can be consumed by other animals. In-field use in bearing fields is only allowed in bait stations.

  This product is relatively inexpensive, and when it is used in in-field bait stations, the stations provide protection from rain, sun, and birds.

  No efficacy against sweet- or protein-loving ants; therefore these ant species become the prevalent species, for which there are no controls.
- Azadirachtin (Agroneem Plus, Azatin XL, Ecozin 3% EC)

  These products are certified organic, have low impact on nontarget organisms, can be effective when applied properly and repeatedly, and can be used in conjunction with foliar feeding (fertilizing).

  Azadirachtin can be expensive to use, because repeated applications are necessary to obtain the desired level of efficacy.
- Neem oil (Trilogy)

  This product is certified organic, can be effective when applied properly and repeatedly, has low impact on nontarget organisms, and suffocates the scales.

  It can be expensive to use, because repeated applications are necessary to obtain the desired level of efficacy. Also, this product is potentially phytotoxic.

- Petroleum Oil (Biocover MLT, Biocover UL, Glacial Spray Fluid, Superior 70, Purespray Green)

  These products can be effective when applied properly and repeatedly, have low impact on nontarget organisms, and suffocate the scales. Purespray Green is certified organic.

  These products can be expensive to use, because they have short (no) residual activity and repeated applications are necessary to obtain the desired level of efficacy. Efficacy is poor if they are not applied properly (i.e., thorough coverage). Also, these products are potentially phytotoxic.
- Buprofezin (Applaud)

  This product is a newly registered insect growth regulator (IGR) that controls scales.
- Pyriproxyfen (Esteem Ant Bait)

  This product is a newly registered IGR that controls ants. It is used for broadcast use in-field.

Biological control:

- Ladybugs.
- Parasitic wasps.
- Chickens.

Other pest management aids:

- Controlling ants helps to control scales.
- Promoting conducive environmental conditions for growth of the white halo fungus (*Verticillium lecanii*).
  - Shade.
  - Increasing humidity and periods of wet leaves.
  - Spraying copper hydroxide (e.g., Kocide) for sooty mold control is not recommended if white halo fungus is present.
- Providing conducive environment for natural enemies (beneficials).
  - Encouraging ladybugs.
  - Encouraging parasitic wasps.
  - Encouraging chickens.
- Keeping trees at optimum health.
- Good nursery practices.
- Intercropping.
- Plant spacing.
- Sanitation.
- Site selection.
- Tank mixing products.

Critical Needs for Management of Green Scale

- Research
  - Conduct field efficacy trials for spirotetramat (Movento). If it is efficacious, obtain IR-4 project approval for registration.
  - Effect of stress on coffee plants.
  - Effect of windy conditions on reducing the presence of beneficial insects and the white halo fungus.

- Regulatory
  - How to legally produce and use your own *Verticillium lecanii* inoculum.
  - Letter of support from the coffee industry to Bayer to speed up registration process of Movento.

- Education
  - Ladybug larvae identification.
  - Effect of copper hydroxide (Kocide) on nontarget organisms.
  - Green scale information to new farmers.
  - How to create favorable environments for beneficials.
  - Cost-benefit ratios of insecticides.
  - Basics of organic chemistry and plant and animal physiology.

Black twig borer (*Xylosandrus compactus*)

The black twig borer is a type of ambrosia beetle. It is not always a serious pest. Infestation levels vary during the crop development cycle, from area to area and year to year. The tiny, brownish-black, cylindrical beetle was first found in Hawai‘i in 1961. Although black twig borer attacks both the lateral and vertical branches, attacks to the laterals are more common. Besides coffee, this pest infests more than 110 hosts, including ohia, avocado, cacao, mango, macadamia, hibiscus, tea, orchids, anthurium, and other ornamental and forest trees and shrubs.

Typical symptoms of the black twig borer's presence include the wilting and death of leaves and wood on lateral branches. This results from the beetle's entry hole, which is less than 1/16 inch in diameter. The leaves and bark beyond the entry hole turn black. Although a single beetle hole may kill a twig, often several burrows are required before the lateral is killed. On the thicker verticals, even heavy infestations do not always kill the branch.

Pregnant females bore into the twig to make a tunnel for eggs and to grow food for the larvae. The female carries a fungus, *Fusarium solani*, which she cultivates within the tunnel to feed her larvae. This fungus produces a toxin that kills the twig and the leaves beyond the entry hole. This beetle generally attacks trees that have been weakened by drought, girdling, heavy pruning, harvesting, standing water, or poor cultural practices (e.g., insufficient fertilizer), but it will also attack healthy trees. Some coffee cultivars are more susceptible than others.

It is estimated that losses up to 20 percent may be experienced. Although infestations may be localized, the injury can be serious, reducing current and future crop yields and crop quality.

Control is difficult, because the insect is inside the branch and its life cycle can be variable across years.

North and South Kona, on Hawai‘i Island, seem to have the highest damage, as reported by growers. There are occasional infestations in the Ka‘u and Puna Districts of Hawai‘i Island. Higher infestations also appear to be associated with lower elevation, drier areas, dry seasons, and the presence of alternate hosts. On Kaua‘i black twig borer is a year-round problem, and it seems to be an increasing problem, especially in the “Typica” variety. No economic threshold has been developed.

Chemical control:
(*Note*: only the chemical controls that are actually used are specifically discussed below. For all insecticides labeled for use on coffee in Hawai‘i, see Appendix 4.)

The insects must be contacted with the spray, so only the adult females are affected. Spraying must be done in the morning hours when the insects are traveling up and down the branches.

- Pyrethrins (Pyganic)
  Pyganic is certified organic and may provide some control. Pyrethrins do kill beneficials, but they have very short residual activity if they are applied in full sun. They photodegrade very quickly, in 10 minutes; therefore, they have fewer effects on beneficials. Pyganic is expensive.
- Piperonyl butoxide + pyrethrins (Pyronyl, Pyreth-It, EverGreen Crop Protection EC 60-6)
  These products may provide some control. They are not certified organic, and like Pyganic, will kill beneficials. But this combination has a short residual because of photodegradation; therefore, it has fewer effects on beneficials. These products are expensive.

Other pest management aids:
- Scouting and monitoring.
- Maintaining good plant health.
- Good cultural practices.
  - Irrigation.
  - Fertilization.
  - Field sanitation, e.g., cutting infested branches below the entry holes, removing them, and destroying them (by chipping, burning, or immersing in water to drown the beetles).
- Intercropping.
- Minimizing plant stress.
- Plant spacing.
- Site selection.

Potential pest management tools and unregistered/new chemistries:
- Sampling procedures.
- Economic thresholds.
- Attractants and repellants.

- Imidacloprid is being evaluated.

Critical Needs for Management of Black Twig Borer

- Research is under way by a Ph.D. student working with a researcher who participated in the PMSP workshop.
  - Relationship between the slope of land and infestation.
  - Collect efficacy data for imidacloprid (Provado and Admire Pro).
  - Demonstrate efficacy of traps and baits.

- Regulatory
  - If efficacy data show that imidacloprid is efficacious against black twig borer, submit data to Bayer and request to have black twig borer listed on the label.

- Education
  - Understand life cycle.
  - Good cultural practices.
  - Understand sampling and thresholds.

Ants: big-headed ant (*Pheidole megacephala*), longlegged ant (*Anoplolepis gracilipes*), white-footed ant (*Technomyrmex albipes*), and little fire ant (*Wasmannia auropunctata*), etc.

Ants are present in all coffee orchards, all the time. Since they feed on the honeydew produced by green scales, ants protect this food-generating source against green scale's natural enemies. They do the same for mealybugs. Ants do damage to irrigation drip emitters and tubing, to tree bark, and perhaps to the root system of coffee trees.

Certain species of ants are specific to certain areas, but in general they are always present. No economic threshold has been developed. Control is needed all the time, but especially when the green scale is prevalent.

Chemical control:
(*Note*: only the chemical controls that are actually used are specifically discussed below. For all insecticides labeled for use on coffee in Hawai'i, see Appendix 4.)

- Hydramethylnon (Amdro Pro)

  Good efficacy against oil-loving ants that farm green scales. Can be broadcast in the nursery and in stumped fields. Becomes ineffective with rain, and can be consumed by other animals. In-field use in bearing fields is only allowed in bait stations. This product is relatively inexpensive, and when it is used in in-field bait stations, the stations provide protection from rain, sun, and birds.

  No efficacy against sweet- or protein-loving ants; therefore, these ant species become the prevalent species, for which there are no controls.

- Pyriproxyfen (Esteem Ant Bait)
  This product has recently received EPA approval. Updated product labels are now available.

Other pest management aids:

- Chickens and geese.
- Can use Tanglefoot® if tree trunk is properly protected.
- Good cultural practices.
- Controlling scale.
- Maintaining good plant health.

Critical Needs for Management of Ants

- Research
  - Vitis Liquid Ant Bait for sugar-loving ants.
  - Effect of EM (effective microorganisms) on ants.
  - Direct effect of ants on trees.
  - Little fire ant control in the field and treatment of high risk commodities.

- Regulatory
  - Registration of boric acid baits.
  - Register sweet-loving ant bait (e.g., Vitis Liquid Ant Bait) to aid green scale control.
  - Little fire ant quarantine.
  - Register spinosad (Conserve) for ant control on organic farms.

- Education
  - Little fire ant monitoring, early detection, and control.
  - Good cultural practices.
  - Understand sampling and thresholds.

Banana moth (*Opogona sacchari*)

Banana moth larvae bore into stumps and young green verticals and feed just under the bark on trunks. The banana moth larva is a scavenger, so it feeds on detritus and bark. Infestations are higher generally after pruning (January to May), and at higher elevations, and in Kona. The important times for control are during pruning and stumping. If infestation is heavy, larvae can kill trees. If they are left untreated, they can devastate orchards. No economic threshold has been developed.

Chemical control:
(*Note*: only the chemical controls that are actually used are specifically discussed below. For all insecticides labeled for use on coffee in Hawai‘i, see Appendix 4.)

- Pyrethrins (Pyganic)
  Pyganic is certified organic and may provide some control. Pyrethrins do kill beneficials, but they have very short residual activity if they are applied in full sun. They photodegrade very quickly, in 10 minutes; therefore they have fewer effects on beneficials. Pyganic is expensive.

Other pest management aids:

- Insect parasitic nematodes.
- Good field sanitation.
- Avoiding herbicide injury.
- Good nursery practices.
- Good plant nutrition.
- Intercropping.
- Irrigation.
- Minimizing plant stress.
- Plant spacing.
- Pruning method.
- Site selection.

Potential pest management tools and unregistered/new chemistries:

- Pheromones.
- Egg parasitoids.
- Spinosad (Success, Entrust)—field residue trials scheduled for the 2008 season have been completed. Samples (green bean, roasted bean, and freeze dried coffee) are being analyzed for residues.

Critical Needs for Management of Banana Moth

- Research
  - Insecticide treatment after pruning.
  - Use of kaolin (Surround WP) as a barrier.
  - Locate more beneficials.
  - Determine economic threshold.
  - Survey and conduct needs assessment.

- Regulatory
  - Register *Bacillus thuringiensis* (e.g., Dipel).

- Education
  - Banana moth biology in coffee.
  - Use of parasitic nematodes.
  - Good field sanitation.

Broad mite (*Polyphagotarsonemus latus*)

Broad mites pierce coffee leaf plant cells and suck the sap. Larvae and adults prefer to feed on the undersides of leaves, usually near the vein. Broad mite feeding injury can reduce plant photosynthesis and create instability in plant-water relations. Corky-textured brown areas may appear between or beside the main veins on the underside on the coffee leaf. Young leaves may be severely curled inward and deformed. Feeding damage causes the terminal coffee leaves to become cupped and distorted. Damage to Kona coffee varies by season, with most damage occurring during summer months. Damage can occur at most elevations where coffee is grown commercially. The broad mite does not vector any known plant diseases.

Symptoms of broad mite damage to coffee include leaf yellowing; twisting, curling, and cupping of terminal leaves; leaf stunting; and abnormally rough leaf texture and appearance. There may be a brown, rough, corky texture and appearance on the leaf surface where mite infestation is severe or of long duration. Affected coffee leaves may be stunted, have yellow areas or veins, and have leathery or corky texture and distorted shape.

Chemical control:
(*Note*: only the chemical controls that are actually used are specifically discussed below. For all insecticides labeled for use on coffee in Hawai‘i, see Appendix 4.)

- Sulfur
  Sulfur applications are effective, but an application may require 2 to 3 weeks to achieve control. Where mites are not distributed evenly throughout a field, areas of higher infestation should be treated more thoroughly and more frequently. Sulfur may interfere with or damage mite predators.

Other pest management aids:
- Natural predators
  Locally occurring mite predators may provide satisfactory control in some areas.

Potential pest management tools and unregistered/new chemistries:
- None.

Critical Needs for Management of Mites

- Research
  – Threshold level.

- Regulatory
  – None.

- Education
  – Identification and control strategies.

Potential Invertebrate Pests

Little Fire Ant *(Wasmannia auropunctata)*

The little fire ant (LFA) was first reported in Hawai‘i in 1999, and it has since invaded a variety of agricultural sites, including nurseries, orchards, and pastures. LFA is currently known to be present on the eastern side of the Big Island and on two adjacent private properties on Kaua‘i. This species is not known to be present in coffee plantations at this time, but plantations may be in close proximity to infestations. Ant colonies are easily transported. Surveys for this and other potentially harmful new species of ants are conducted periodically on a limited basis.

LFA are small (1/16 inch), slow moving, orange-red ants that have a burning sting that may raise bumps that last for several weeks. It is an agricultural pest that is easily dislodged during harvest or other work, which makes finding and keeping agricultural workers difficult. LFA also nurture populations of Homoptera (e.g., scales, aphids, mealybugs, etc.). LFA are known to have negative impacts on many animals, including vertebrates (pets and livestock) and invertebrates. In areas of high infestation, ants sting the eyes of pet cats and other animals, resulting in blindness.

If LFA were to infest coffee, control or eradication would be difficult. But it would have to be undertaken for the long-term health of the industry and of fieldworkers. LFA poses greater threats to production areas such as Kona, where coffee is hand-harvested. Control options are limited, and none exist at this time for control in organic plantations. Conventional baits that can be effective against LFA elsewhere are not effective under Hawai‘i’s humid conditions. Most effective is hydramethylnon (Amdro, in bait stations), but it cannot be broadcast. Pyriproxyfen (Esteem broadcast bait) is somewhat effective. In field studies in Hawai‘i fruit orchards, neither product achieves 100 percent reduction when orchards are treated every 2 weeks for 16 weeks. The biology of the ant makes chemical control difficult. LFA forms supercolonies that may exceed 90 million ants per acre, and each nest contains multiple queens. LFA can nest on the ground, in leaf litter, in tree cavities or under bark, and in the canopy. No products are labeled for use under these conditions at this time. There are no baiting methods to control ants in trees, from which LFA can fall on workers conducting pruning or harvesting. Infestations or suspicious ants should be reported immediately by calling the State Pest Hotline at (808) 643-PEST (7378).

Stinging nettle caterpillar (*Darna pallivitta*)

Like the little fire ant, stinging nettle caterpillar is potentially a pest of coffee because of its ability to inflict nasty stings on people while they are harvesting. This pest was first discovered in Hawai‘i in September, 2001, at a foliage nursery in Pana‘ewa, on the eastern side of the island of Hawai‘i. The nettle caterpillar’s stinging, spiny hairs have a physical effect on human skin similar to that of fiberglass. In addition, the spines release an irritant (a mixture of histamines) that is produced by a poison gland. The irritant causes the skin to burn and itch. If spines get into the eyes, the irritation can be acute.

In Hawai‘i, the nettle caterpillar has been found on more than 30 plants, including palms, pasture and ornamental grasses, weeds, and foliage plants. New infestations of stinging nettle caterpillar should be reported immediately by calling the State Pest Hotline at (808) 643-PEST (7378).

Vertebrate Pests

Feral pigs and rats

On Kaua‘i, feral pigs are becoming a nuisance. Attempts to control them with traps and snares have had only fair to poor success. Elsewhere, rats as well as feral pigs can be a problem.

Chemical control:

- None.

Other pest management aids:

- Trapping and removal of feral pigs.
- Enclosed rat bait stations on the perimeter of the orchard.
- Fences for feral pigs.
- Cats and dogs for rat control.

Potential pest management tools and unregistered/new chemistries:

- None.

Critical Needs for Management of Vertebrate Pests

- Research
  - None.
- Regulatory
  - None.
- Education
  - None.

Diseases

Cercospora leaf spot (or brown eye spot) and berry blotch (*Cercospora coffeicola*) and anthracnose (*Colletotrichum gloeosporioides*)

Coffee diseases reduce yields of current and future crops, decrease coffee quality, make pulping difficult, may affect young shoots, and can be problematic in the nursery. In Kona, these diseases are more prevalent during the wet summer months and at harvest. Diseases should be controlled prior to harvesting. No economic thresholds have been established.

Cercospora diseases are found in coffee-growing areas worldwide. Cercospora leaf spot and berry blotch are two phases of a common disease caused by the plant-pathogenic fungus *Cercospora coffeicola*. It is common in Hawai‘i and can be economically important at some locations or in some seasons because of the costs associated with managing it and because of the damaging effects on plant growth and cherries (e.g., yield reduction, berry shriveling, premature berry drop, premature ripening, and reduced coffee grade). Coffee beans may be stained or off-grade. Parts of the cherry pulp may adhere to the parchment, resulting in difficulty in coffee milling, discolored parchment and beans, and a sour taste in the processed beans. Percent injury is unknown, but it can be significant in certain years. Overall distribution throughout the state is unknown, but it is probably widespread. No economic thresholds have been established.

Pathogen dispersal is by spores (conidia) that are windborne (mostly during the daytime). Spores may also be spread by splashing rain, human contact (such as movement of workers), and by machinery within coffee fields and nurseries.

Good growing conditions, sufficient air circulation, adequate fertilization, and irrigation are necessary to prevent the disease from becoming established. High humidity, rain, warm temperature, nutrient deficiencies, and drought stress favor the disease. Drought can render trees susceptible to this problem when growth resumes, as can insufficient fertilizer. Additional factors that predispose coffee to infection include insufficient shade, excessive weed competition, herbicide injury, and the presence of root disease. The highest risk for infection occurs when the temperature range is 20 to 28°C (68 to 82.4°F) and there are from 36 to 72 hours of continuous environmental wetness. Exposed, unshaded trees (without sufficient fertilizer) and nursery seedlings are most susceptible.

Symptoms appear as small, chlorotic spots on leaves that expand to 3/16 to 5/8 inch in diameter. The outer portion of the leafspot becomes brown, and the center becomes gray-white. The spot’s eye-like appearance distinguishes it from other leaf spot diseases. Affected leaves may defoliate prematurely.

Infections can occur at any stage of berry development. Spots can occur on the cherries, appearing as a sunburned, black, dried, elliptical scar on the skin. These make the cherry difficult to pulp and may reduce the green bean quality. Infections that penetrate to the seed may cause the pulp to adhere to the parchment during processing, causing damage to the product. Diseased cherries may be subject to attack and further degradation by opportunistic bacteria or fungi such as *Colletotrichum gloeosporioides* (a ubiquitous fungus that causes anthracnose of many crops). The conspicuous presence of *C. gloeosporioides* as an opportunistic and secondary invader of cherries damaged first by *C. coffeicola* can confuse the disease diagnosis.

Anthracnose (*C. gloeosporioides*) is widespread, even in Hawai‘i. Early symptoms are brown, sunken lesions on green cherries. Small, black, spore-producing structures may appear in the lesions. Lesions grow, covering the green cherry, causing it to shrivel and blacken, and eventually destroying the bean. Dried, shriveled cherries may drop or hang on to the tree, but

these are not the same as dried cherries that occur with overbearing dieback. Flowers can also be affected. *C. kahawae* is the aggressive species known as coffee berry disease, currently found only in Africa.

Chemical control:
(*Note*: only the chemical controls that are actually used are specifically discussed below. For all fungicides labeled for use on coffee in Hawai‘i, see Appendix 5.)

- Copper hydroxide (Kocide, Champion, Champ, Nu-Cop, etc.). Copper fungicides are only necessary in a serious outbreak. Copper is effective and is also a micronutrient. However, it can adversely affect the micronutrient balance and therefore be toxic to coffee if applied too frequently or at high rates. It is potentially toxic to aquatic life, and it is an eye hazard to humans. Its use is limited (restricted) in organic production.

  A critical issue is that copper hydroxide kills the white halo fungus, *Verticillium lecanii. V. lecanii*, which is very effective in controlling the serious coffee pest green scale, is very sensitive to copper hydroxide. Laboratory studies have shown that this copper compound can effectively suppress *V. lecanii* for more than 4 months.
- Neem Oil (Trilogy). Used in organic production.

Other pest management aids:
- Good air circulation.
  - Plant spacing.
- Field orientation (to optimize sunlight and airflow).
- Adequate fertilization.
- Soil health.
- Soil fertility.
- Field sanitation.
  - Removing infected leaves.
  - Removing debris from pruned trees from the field.
- Growing under shade—in appropriate locations.
- Avoiding herbicide injury.
- Composting, organic matter.
- Foliar feeding.
- Good nursery practices.
- Good plant nutrition.
- Intercropping.
- Irrigation with pathogen-free water.
- Minimizing plant stress.
- On-time harvest.
- Site selection.
- Applying overhead irrigation early in the day.
- Not irrigating nursery plants too frequently.

Potential pest management tools and unregistered/new chemistries:
- None.

Critical Needs for Management of
Cercospora Leaf Spot (Brown Eye Spot) and Berry Blotch and Anthracnose

- Research
  - Surveys of distribution.
  - Establish economic thresholds.
  - Seek alternative chemicals.
  - Determine if copper fungicides are toxic to the white halo fungus (*Verticillium lecanii*).

- Regulatory
  - None.

- Education
  - Good air circulation.
  - How to orient fields (to optimize sunlight and airflow).
  - Adequate irrigation at adequate intervals.
  - Improving soil health.
  - Adequate soil fertility.
  - Field sanitation practices (remove infected leaves).
  - Shade in appropriate locations.

Damping-off, root rots (*Fusarium* spp., *Phytophthora* spp., *Pythium* spp., *Rhizoctonia* spp.)

These fungi can attack seedlings in the nursery (preplant) and can be carried over into the field when transplanted. Symptoms are exacerbated when plants are overwatered. This disease occurs year-round and across the state. No economic threshold has been established, but it is probably very low.

Rhizoctonia and Pythium root rots may occur in coffee fields where soil is poorly drained or very moist for long periods of time. These pathogens have relatively wide host ranges and may cause coffee plant death. It is very important to avoid excessive irrigation and to move irrigation emitters away from plants gradually over time during the months after transplanting. These diseases are much more easily prevented than controlled.

Chemical control:
(*Note*: only the chemical control that is actually used is specifically discussed below. For all fungicides labeled for use on coffee in Hawai‘i, see Appendix 5.)

- Phosphorous acid (Fosphite, Fungi-Phite, Rampart). Good against *Pythium* and *Phytophthora*, but not for other fungi.

Other pest management aids:
- Proper irrigation with pathogen-free water.

  - Irrigating early in the day.
  - Do not irrigate too frequently—let soil dry out somewhat between irrigations.
- Plant health.
- Nursery sanitation.
- Sterilizing, pasteurizing, or fumigating potting media.
- Non-soil potting mix.
- Hydroponically grown seedlings.
- Do not transplant seedlings below their soil line.
- Field sanitation.

Potential pest management tools and unregistered/new chemistries:

- None.

Critical Needs for Management of Damping-Off

- Research
  - Collect data on prevalence of this problem.
  - Collect efficacy data on fungicides to register.

- Regulatory
  - Register nonbearing fungicides, e.g., soil drench.

- Education
  - Proper irrigation with pathogen-free water.
  - Plant health.
  - Nursery sanitation. Sterilize, pasteurize, or fumigate potting media.
  - Non-soil potting mix.
  - Hydroponically grown seedlings.
  - Do not transplant seedlings below their soil line.
  - Field sanitation.

Potential Disease

Coffee rust (*Hemileia vastatrix*)

The coffee rust disease fungus attacks leaves of coffee trees, causing severe defoliation, reduction in photosynthesis, and consequent loss of vigor and yield. Rust was at first confined to Southeast Asia and southwestern Africa. But because rust spores can survive wind dissemination, and due to heavy international traffic, the fungus spread rapidly and is now found in all coffee-growing areas worldwide—except Hawai‘i. In areas where it occurs, the disease has resulted in expensive control measures, from eradication attempts to fungicide spray programs and resistance breeding. Most industry representatives consider it only a matter of time before it enters the Hawaiian Islands, where it is predicted to be a severe problem.

Chemical control:

- Copper oxychloride and other metallic copper fungicides are most often used.

Other pest management aids:

- Breeding for resistance while maintaining good quality and yields.
- Management of light intensity, providing adequate shading.
- Overbearing trees are more susceptible.

Potential pest management tools and unregistered/new chemistries:

- None.

Critical Needs for Management of Coffee Rust

- Research
  - Determine/verify susceptibility of Hawaiian coffee varieties to rust.
  - Develop new Arabica varieties with rust resistance.
  - Rust-resistant lines (not Arabica) available at CTAHR Kona experiment station.
  - Include rust resistance as a factor in coffee breeding programs.
  - Consider creating a GMO rust-resistant version of “Kona Typica,” which should have minimal impact on flavor.

- Regulatory
  - Maintain strict quarantine procedures and regulations against possible introduction.

  - Prepare lists of possible fungicides for emergency clearance in case they should be needed.

- Education
  - Disease recognition.
  - Immediate response and reporting if rust is found.
  - Response procedures for control and elimination.

Nematodes

Root-knot nematode (*Meloidogyne* spp.), Kona coffee root-knot nematode (*Meloidogyne konaensis*)

Nematodes are a serious problem for coffee on Hawai‘i Island, causing conditions with names such as “transplanting decline,” “replant problem,” “nutritional stress,” and “Kona wilt.” Trees are killed quickly when they are young and slowly when they are older. Severely affected trees are stunted and unthrifty; have thin and wobbly stems; are easily uprooted by hand; have dying or declining branches; have leaves that are yellowing, brown and/or wilting; and have roots that are galled, swollen, corky, and rotten. Yields are always reduced.

Once infested, soils remain infested. Root-knot nematodes can survive for months to a few years as eggs or juveniles in the soil or within root fragments in the soil. They are primarily spread by water, machinery, animals, and humans. Planting of infected seedlings into uninfested soil is one of the most common and effective ways these pests are dispersed. They move very short distances (only an inch or so) under their own power. Unfortunately, it is very unlikely that these pests can be totally eliminated from an infested farm due to their great numbers and their ability to survive adverse conditions. The best way to deal with them is to try to continually reduce their population numbers to levels that do not cause great damage. This is accomplished by finding ways to interrupt the nematode life cycle or to slow it down.

Nematodes are considered the biggest long-term threat to coffee production in Kona. Once a tree is infested and declining, replacement is necessary with nematode-resistant rootstock such as “Fukunaga” (*Coffea liberica* var. *dewevrei*).

Control is needed in the nursery (preplant) if soil and volunteer seedlings are used. It is best to germinate seeds and grow the seedlings in sterile media. If the farm is already infested, resistant rootstocks are necessary, because planting healthy “Kona Typica” seedlings into nematode-infested soil will result in disease soon after planting. Nematodes can be transported in the roots of volunteer coffee seedlings (*pulapula*) if these are moved to new planting sites. This should not be done unless the soil of the orchard they are taken from has been assayed and declared free of the nematode. When seedlings are grown in containers in media that includes soil, this also should be analyzed for the presence of nematodes.

Fields can be left fallow with the addition of organic amendments to reduce nematode populations. Infestations can be localized, and Kona growers estimate approximately 10 percent annual losses due to nematodes. However, some farms have had to completely replant.

Nematodes occur year-round with Kona having its own species of root-knot nematode. The economic threshold is very low if not zero. If a grower detects any nematodes, he or she has a

problem. A nematode-resistant "Kona Typica" has been genetically engineered but cannot be field-tested due to marketing concerns in Kona.

Chemical control (preplant only):

- Metam sodium (Vapam). An effective preplant fumigant that can also be used in the nursery. Metam sodium also controls weeds, and could be used as a "spot" treatment for areas of the field that need to be replanted. Tarping or sealing with irrigation is needed to prevent the fumigant from escaping; therefore, metam sodium is not useful in rocky or volcanic soils. Metam sodium is a biocide, so it also kills beneficial organisms and existing coffee trees. The product is expensive.
- 1,3-Dichloropropene (Telone II). Also an effective preplant fumigant that can be used in the nursery. However, unlike metam sodium, 1,3-Dichloropropene does not control weeds. Tends to be more effective on rocky soils than metam sodium. Tarp or plastic mulch is required for application, and it is a restricted-use pesticide. The product is expensive.

Other pest management aids:

- Using grafted trees with resistant rootstock (such as "Fukunaga").
- Using green manures, e.g., "Tropic Sun" Sunn Hemp (*Crotalaria juncea*).
- Soil health.
  - Adding organic matter, especially chicken manure and cherry skins.
- Sampling soil (diagnostic).
- Using sterile potting media in the nursery.
- Fallowing land with a nemastatic (non- or poor nematode host) cover crop such as Sunn Hemp incorporated into the soil.
- Removing weeds that are hosts to nematodes.
- Avoiding nematode introduction from seedlings, tools, equipment, soil, etc.
- Avoiding herbicide injury.
- Crop rotation.
- Foliar feeding.
- Good nursery practices.
- Good plant nutrition.
- Growing under shade.
- Minimizing plant stress.
- Sanitation.
- Site selection.
- Planting from seed in nursery.
- Variety selection.

Potential pest management tools and unregistered/new chemistries:

- *Paecilomyces lilacinus* (Melocon and several other trade names). A biopesticide that has shown promise in controlling root-knot nematodes in vegetable, fruit, and tuber crops. The fungus strain, PL 251, is parasitic to multiple nematode life stages, in particular the

eggs. In Hawai‘i this strain has given multiple positive results in pineapple. PL 251 is not registered for use on coffee.
- Identifying new resistant rootstocks in state.
- Identifying new resistant rootstocks out of state.

Critical Needs for Management of Root-Knot Nematodes

- Research
  - Find effective nematicides for in-field use (post-plant).
  - Survey of distribution.
  - Identify additional nematode-resistant rootstocks.
  - Develop new Arabica varieties resistant to nematodes.

- Regulatory
  - Register the GMO “Kona typica,” developed by the University of Hawai‘i and the Hawai‘i Agriculture Research Center.

- Education
  - Use grafted trees with resistant rootstock (“Fukunaga”).
  - Do not use *pulapula* (volunteer seedlings).
  - Use green manures.
  - Soil health.
    - Add organic matter, especially chicken manure and cherry skins.
  - Sample soil (diagnostic).
  - Use sterile potting media in the nursery.
  - Fallow land with nemastatic (non- or poor nematode host) cover crop, such as Sunn Hemp.
  - Remove weeds that are hosts to nematodes.
  - Avoid introduction from seedlings, tools, equipment, soil, etc.

Weeds

Weeds (grasses, broadleaves, and vines) must be controlled to obtain good coffee yields. Growers estimate that about 15 to 20 percent of their total annual operating costs are for weed control. More specifically, approximately 5 percent is for grass control, 10 to 15 percent is for vine control, and less than 5 percent is for broadleaf control. This assumes that weeds are generally well-managed and that extensive hand-weeding is not needed. However, weeds are a major problem for organic production, and hand-weeding is a major cost. As with other crops, weeds compete for water, sunlight, and nutrients; therefore, without weed control, weeds will out-compete young trees and challenge mature coffee. Weedy vines interfere with mechanical harvesting and can provide an environment conducive to development of fungal diseases. Weeds are a problem year-round, but especially during the wet seasons. Some grass and broadleaf weeds can be alternate hosts for nematodes.

Grasses

Grasses are a problem in all coffee-growing areas, but they tend to be more of a problem on former sugarcane lands. Grasses provide a good habitat for rodents and are a major fire hazard during the dry season. No economic thresholds have been developed for grasses.

Broadleaves

Broadleaves are a problem in all coffee-growing areas. No economic thresholds were developed for broadleaves.

Vines: morningglory, maunaloa (*Canavalia cathartica*), and ivy gourd (*Coccinia grandis*) (and emerging vine pests: lablab, *maile pilau*, desmodium, and others)

Morningglory, maunaloa, and ivy gourd are considered the worst weeds in coffee. Total control is necessary, because once they invade the trees they are difficult to remove and will eventually shade out the coffee. These vines root deeply, so chopping them off at the soil surface will not control them. Control with currently-registered herbicides is inadequate. Much of the control must be done by hand, especially if vines grow on the coffee trees. Vines occur throughout the state, but they tend to be worse in the dry areas where coffee is normally irrigated and mechanically-harvested. Vines must be manually removed from the coffee trees before the mechanical harvesters can go through the field. This is generally performed just before harvest. Also, especially after stumping or hedge pruning, vines become a problem because of the increase in sunlight. Vine control can be conducted year-round.

Chemical control:
(*Note*: only the chemical controls that are actually used are specifically discussed below. For all herbicides labeled for use on coffee in Hawai‘i, see Appendix 6.)

- Fluazifop-P-butyl (Fusilade). An effective selective postemergence grass herbicide with no residual activity. Spray coverage needs to be thorough, and grasses must be actively growing for good control. Mature and flowering grasses are difficult to control and often not adequately controlled with fluazifop-P-butyl. Most coffee varieties are tolerant of this material, but application to some varieties can result in phytotoxicity or yellowing of new growth.
- Glyphosate (Roundup, et al.). An effective broad-spectrum systemic postemergence herbicide with no residual activity. It degrades in the environment relatively quickly, is immobile in soil, and has low mammalian toxicity; therefore, of the herbicides used in coffee, glyphosate has the shortest worker restricted-entry interval (only 4 hours). The 1-day preharvest interval (Roundup Weathermax) allows for flexibility near the harvesting period. Glyphosate is somewhat weak on legumes. It needs to be applied to actively growing plants with sufficient leaf area and may be more effective with added adjuvants such as ammonium sulfate and additional surfactants. Drift onto coffee is detrimental (i.e., phytotoxic), with symptoms mimicking zinc deficiency.

- Paraquat (Gramoxone Inteon). An effective broad-spectrum contact postemergence herbicide with rapid burndown on small weeds and with no residual activity. It is only partially effective on most mature weeds, where regrowth often occurs. Paraquat can be used for sucker or volunteer control or to skirt-prune trees. It is immobile in soil. Postemergence activity is synergistic when tank-mixed with oxyfluorfen (Goal). Because of paraquat's high mammalian toxicity it is a restricted-use pesticide.
- Oxyfluorfen (Goal, GoalTender). An effective broad-spectrum pre-emergence herbicide for grass (especially Guinea grass) and broadleaf weed control with postemergence activity on many broadleaf weeds, including some vines. Oxyfluorfen is the only pre-emergence herbicide currently registered for coffee in Hawai'i. It is moderately effective on some large-seeded broadleaf weeds such as Aiea morningglory. The control of some weeds, like Spanish needle, is rate-dependent. It is most effective as a pre-emergence herbicide when soil moisture is adequate, especially during the wet winter months. Oxyfluorfen is somewhat immobile, but volatilization can occur after the first rainfall event when the application is made to dry soil. It provides good soil residual to control weeds up to 120 days under ideal conditions. Oxyfluorfen with additives has good postemergence activity on Aiea morningglory and many other broadleaf weeds, but it is very weak on grasses and sedges. Coffee is quite tolerant of oxyfluorfen. The EC formulation has a strong odor, but a new formulation (GoalTender) with less of an odor is available.
- Pelargonic acid (Scythe). A quick-acting, postemergence herbicide that is effective against small broadleaf weeds. Pelargonic acid is weak on grasses, is not organic certified, has a strong odor, and is expensive.
- Carfentrazone (Aim). A postemergence herbicide that is effective against small broadleaves, but once broadleaf weeds grow beyond 2 to 3 inches in height, control is fair to poor.

Other pest management aids:

- Mowing (not for vines).
- Hand-pulling.
- Mechanical cultivation.
- Animals, e.g., seven to eight geese per acre, one sheep per acre.
- Flaming.
- Ground covers.
- Mulch (cherry skins, parchment husks, wood chips, branches, macadamia nuts husks, banana leaves, Guinea grass).
- Fences (to keep out wild turkeys or chickens that may carry weed seeds).

Potential pest management tools and unregistered/new chemistries:

- 2,4-D for broadleaves and vine control; however, Dow AgroSciences is not supportive unless additional phytotoxicity data are provided (multiple locations, multiple years).
- Oxyfluorfen (Goal) over-the-top of coffee for morningglory control. IR-4 field residue trials have been completed. Samples (green bean, roasted bean, and freeze dried coffee) are being analyzed for residues.
- Glufosinate (Rely) IR-4 project, pending EPA decision on dietary risk.

- Ongoing research on different cover crops for weed and erosion control in mechanized production.

Critical Needs for Management of Weeds

- Research
  - Find effective pre-emergence herbicides.
  - Find effective postemergence spray-over-coffee herbicide for vine control.
  - Weedy shrub and tree control.

- Regulatory
  - Register pendimethalin (Prowl, pre-emergence herbicide) in coffee.
  - Register 2,4-D for broadleaf and vine control.

- Education
  - Drift control.
  - Calibration.
  - Surfactants and adjuvants.
  - Improving efficacy with additives.
  - PPE (personal protective equipment).
  - Mowing.
  - Hand-pulling.
  - Mechanical cultivation.
  - Animals, e.g., geese, sheep.
  - Flaming.
  - Ground covers.
  - Cover crops.

Postharvest Storage Pests

Indian meal moth (*Plodia interpunctella*)

Indian meal moth (IMM) is relatively minor, but its increasing presence is indicative of poor storage conditions and a lengthy storage period (i.e., greater than 1 year). This pest can become serious if it is not controlled or if remedies to poor storage conditions are not implemented. This pest bores into the green bean (not parchment), and the damage is seen by inspectors as a defect. Higher elevations and lower temperatures appear to reduce incidence of this pest, but it is found throughout the state. No economic threshold was developed for this pest.

Chemical control:

- Fumigation.
  - Magnesium phosphide.
  - Methyl bromide (quarantine).

Other pest management aids:

- Pheromone traps.
- Storing coffee as parchment.
- Controlling environment.
  - Temperature and humidity.
- Sanitation.

Potential pest management tools and unregistered/new chemistries:

- Ozone is being registered by USDA for quarantine use by the U.S. Pacific Basin Agricultural Research Center, Hilo.

Critical Needs for Management of Indian Meal Moth

- Research
  - Measure extent of the problem.
  - Determine the effect of freezing green coffee.
  - Determine economic threshold.
  - Survey storage facilities.
  - Secondary impact of boring insects in relation to fungal pests.

- Regulatory
  - Stop bringing in IMM with cereals.
  - CO_2 registration and controlled atmosphere.
  - Methyl bromide for fumigation.
  - Pyrethroid insecticide.

- Education.
  - Rapid turnover in storage.
  - Best practices.

Mildew (*Aspergillus* spp., *Cladosporium* spp., *Fusarium* spp.)

These fungi can ruin the appearance of the bean (physical damage) and the flavor quality of the bean (chemical damage) if they are not controlled, and they can be a big problem. If they are controlled early and beans are dried, damage may be tolerable. Mildews are prevalent during the rainy season and in wetter regions. Also, higher elevations seem to have more mildew problems. The economic threshold is determined by presence or absence. If mildew is detected, the grower/processor must do something to control it. Although it is not currently believed to be a serious problem, Ochratoxin A, produced by *Aspergillus* spp. and *Penicillium* spp., is a carcinogen and is more common in dry processed coffee.

Chemical control:

- None.

Other pest management aids:

- Environmental control.
  - Temperature and humidity.
- Drying the coffee to the low end of allowable moisture content (i.e., 12 percent).
- Mechanical drying.
- Recirculating air in storage facilities.
- Storing as parchment.
- Hypobaric (low pressure or vacuum) storage.

Potential pest management tools and unregistered/new chemistries:

- Hydrated lime.

Critical Needs for Management of Mildew

- Research
  - Identification of fungi.
  - Identification of potential toxic compounds (e.g., aflatoxins, ochratoxin A).
  - Relationship with sooty mold fungi.

- Regulatory
  - Hydrated lime.
  - Proper storage.

- Education
  - Mechanical dryers.

- Proper drying.
- Proper storage standard operating procedures.

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Appendix 1: Green Scale Threshold

To prevent yield losses from green scale, Bittenbender and Smith recommend applying an infestation index to determine when an orchard has a scale problem severe enough to warrant starting a spray program.

Orchards should be monitored in the dry months by collecting leaves from selected sampling stations. There is usually one sampling station for every 5 acres. On farms less than 5 acres, 10 trees are randomly sampled throughout the orchard if a scale problem already exists. Two leaves, one from the top and one from the bottom of each of the 10 trees, are collected. The upper and undersides of each leaf are checked, and the "scale score" for each leaf is recorded.

Number of adult scales per leaf	Level of infestation	**Scale Score**
0	No scales	**0**
1–10	Light	**1**
11–50	Medium	**2**
50+	Heavy	**3**

The number of leaves at each level of infestation is multiplied by the scale score, and the resulting products are added together. This total is divided by the number of leaves with scales to obtain the average density of scale infestation on the leaves. The average density of scale infestation is multiplied by the percentage of leaves with scale and divided by 3. This number is the "infestation index." Bittenbender and Smith recommend treating for scale when the infestation index reaches 6.

Appendix 2: Crop Cycle and Pest Occurrence Timelines for Hawaiʻi Coffee

Crop Cycle (X = statewide)

Crop Stage	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Bloom/pollination	XXXX	XXXX	XXXX	XXXX							XXXX	XXXX
Seed/cherry development (H = high elevation)				XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	HHHH
Cherry harvest (H = high elevation)	HHHH	HHHH	HHHH	HHHH			XXXX	XXXX	XXXX	XXXX	XXXX	XXXX
Vegetative growth (H = high elevation)				XXXX	XXXX	XXXX	XXXX	XXXX	HHHH	HHHH		

Pest Occurrence (X = statewide)

Insects	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Banana moth (more in stump-pruned)		KKKK	KKKK	KKKK	KKKK	KKKK	KKKK	KKKK	KKKK	KKKK	KKKK	KKKK
Black twig borer	XXXX	XXXX	XXXX	XXXX				XXXX	XXXX	XXXX	XXXX	
Green scale (*Coccus viridis*) (K = Kona, A = Kauaʻi)	KKKK	KKKK AAAA	KKKK AAAA	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX			

Diseases & Nematodes	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Leaf spot	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX					
Berry blotch					XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	
Sooty mold (*Capnodium* spp.) (K = Kona, A = Kauaʻi, O = Other)	KKKK	KKKK AAAA	KKKK AAAA	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	OOOO		
Kona root-knot nematode	KKKK	KKKK	KKKK	KKKK	KKKK	KKKK	KKKK	KKKK	KKKK	KKKK	KKKK	KKKK
Weeds	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Grasses and broadleaves (K = Kona, H = Oʻahu, O = other)	OOOO	OOOO	XXXX	XXXX	KKKK	KKKK	KKKK	KKKK	KKKK	KKKK	KKKK	HHHH
Broadleaf vines (mechanized production)	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO

Appendix 3: Worker Activity Table for Hawai'i Coffee

Worker Activities (X = statewide)												
Activity	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Fertilize (A = Kaua'i)	AAAA	XXXX	XXXX	XXXX	AAAA	XXXX	XXXX	XXXX				XXXX
Irrigate		KKKK	KKKK		XXXX	XXXX	XXXX	XXXX	XXXX	XXXX		
Prune/hedge/set verticals (and remove suckers [S])	XXXX	XXXX	XXXX	XXXX	SSSS	SSSS	SSSS					
Harvest: mechanized									XXXX	XXXX	XXXX	XXXX
Harvest: hand (H = high elevation)	HHHH	HHHH	HHHH	HHHH			XXXX	XXXX	XXXX	XXXX	XXXX	XXXX
Pest control: herbicide	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX				
Pest control: mow (A = Kaua'i)	AAAA	AAAA	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX
Pest control: insecticide	Variable, dependent on population levels.											
Pest control: fungicide (K = Kona)			KKKK	KKKK	KKKK	KKKK	KKKK					
Pest control: rodenticide	Variable, dependent on population levels.											
Replant (K= Kona, O = Other)	OOOO	OOOO	OOOO	XXXX	XXXX	KKKK	KKKK	KKKK				

Appendix 4: Efficacy of Pest Management Tools for Suppression of Insects and Other Invertebrate Pests on Coffee in Hawai'i

	Pest						
Management Tool:	**Ants**	**Banana moth**	**Black twig borer**	**Indian meal moth**	**Green scale**	**Mites**	**Comments**
Registered Pesticides							
Aluminum phosphide (Fumitoxin, Phostoxin, Weevil-cide for stored commodity fumigation)	-	-	-	*	-	-	
Azadirachtin (Agroneem Plus, Azatin XL, Ecozin 3% EC)	-	-	-	-	P - F	*	
Buprofezin (Applaud)	-	-	-	-	+	-	New registration.
Clarified hydrophobic neem oil (Trilogy)	-	-	-	-	P - F	*	
Fenoxycarb (Award—non-bearing only)	-	-	-	-	-	-	
Hydramethylnon (Amdro Pro)	E (lipophilic)	-	-	-	-	-	No efficacy against sweet- or protein-loving ants.
Imidacloprid (Admire Pro, Provado)	F	?	?	-	G - E	-	
Magnesium phosphide (Fumi-Cel, Fumi-Strip)	-	-	-	*	-	-	
Methyl bromide (Metabrom Q for stored commodity quarantine fumigation)	-	-	-	*	-	-	

	Pest						
Management Tool:	**Ants**	**Banana moth**	**Black twig borer**	**Indian meal moth**	**Green scale**	**Mites**	**Comments**
Registered Pesticides (cont.)							
Neem oil	-	-	?	-	?	?	May be effective against black twig borer, but not labeled for black twig borer.
Petroleum distillate, oils, solvent, or hydrocarbons; also parrafinic hydrocarbons, aliphatic hydrocarbons, parrafinic oil (Biocover UL, Biocover MLT, Glacial Spray Fluid, Purespray Green, Superior 70)	-	-	-	-	F - G	*	Repeated use required for efficacy.
Piperonyl butoxide + pyrethrins (Pyreth-It, Pyronyl, EverGreen Crop Protection EC 60-6)	-	-	-	-	*	*	
Potassium salts of fatty acids (M-Pede)	-	-	-	-	F	*	
Potassium salts of fatty acids + sulfur (3-in-1)	-	-	-	-	*	*	Difficult to obtain complete coverage for good efficacy.
Pyrethrins (Pyganic Crop Protection EC 1.4 II, Pyganic Crop Protection EC 5.0 II)	-	?	-	-	P	*	
Pyriproxyfen (Esteem Ant Bait)	G-E	-	-	-	+	-	New registration; ant bait formulation for fat-loving ants only
SLN Registered Materials							
Petroleum oil (SLN HI: 910008) (Superior 70)	-	-	-	-	F - G	*	Repeated use required for efficacy.

	Pest						
Management Tool:	**Ants**	**Banana moth**	**Black twig borer**	**Indian meal moth**	**Green scale**	**Mites**	**Comments**
Unregistered Materials							
Spirotetramat (Movento)	-	-	-	-	G	*	
Pyrethroid	-	-	-	*	-	-	
CO_2	-	-	-	*	-	-	
Potential Pest Management Tools							
Sampling procedures	?	?	+	?	X (procedure established for green scale)	?	Black twig borer.
Economic threshold	?	?	+	?	X (established for green scale)	?	Black twig borer.
Attractants and repellents	?	?	+	?	?	?	Black twig borer.
Pheromones	?	+	?	?	?	?	Banana moth.
Egg parasitoids	?	+	?	?	?	?	Banana moth.
Spinosad	?	+	?	-	-	?	Banana moth.

	Pest						
Management Tool:	**Ants**	**Banana moth**	**Black twig borer**	**Indian meal moth**	**Green scale**	**Mites**	**Comments**
Biological Controls							
Ladybugs	-	-	-	-	P	-	Present but not efficient.
Biological Controls (cont.)							
Parasitic wasps	-	-	-	-	P	-	Probably present but not efficient.
Chickens	-	-	-	-	-	-	
Cultural/Nonchemical Controls							
Chickens/geese	P	-	-	-	-	-	
Controlling storage temperature and humidity	-	-	-	?	-	-	
Field sanitation	*	P	F	-	+	-	
Kaolin	-	?	?	-	?	+	
Parasitic nematodes	-	?	-	-	-	-	
Pheromone traps	-	-	-	-	-	-	
Plant health	-	?	P	-	P (for prevention)	+	

	Pest						
Management Tool:	**Ants**	**Banana moth**	**Black twig borer**	**Indian meal moth**	**Green scale**	**Mites**	**Comments**
Cultural/Nonchemical Controls (cont.)							
Promoting conducive environment for natural enemies	-	-	-	-	+	+	
Shade	-	-	-	-	*	-	
Storage sanitation	-	-	-	+	-	-	
Storing coffee as parchment	-	-	-	*	-	-	
Tanglefoot	+	-	-	-	-	-	
White halo fungus	-	-	-	-	G - E	-	
Good nursery practices	-	-	?	-	+	?	
Intercropping	-	-	?	-	?	?	
Plant spacing	-	-	-	-	-	?	
Site selection	-	?	?	-	?	?	
Tank mixing products	-	-	-	-	G	-	Provado + oil.
Minimizing plant stress	-	?	+	-	?	?	

	Pest						
Management Tool:	**Ants**	**Banana moth**	**Black twig borer**	**Indian meal moth**	**Green scale**	**Mites**	**Comments**
Cultural/Nonchemical Controls (cont.)							
Scouting/monitoring	**?**	**?**	**?**	**?**	**G**	**?**	Threshold developed for green scale.
Avoiding herbicide injury	**-**	**-**	**?**	**-**	**-**	**?**	
Good plant nutrition	**G**	**?**	**G**	**-**	**G**	**?**	
Irrigation	**X**	*****	**?**	**-**	**?**	**?**	Improperly placed lines may increase ant problems.
Pruning method	**G**	**?**	**G**	**-**	**-**	**?**	

Efficacy rating scale: E = excellent (90–100% control); G = good (80–90% control); F = fair (70–80% control);
P = poor (<70% control); ? = no data, more research needed;
- = not applicable or not used; + = no data, but successful on other related organisms;
X = used but not a stand-alone management tool; * = not enough experience to rate.

Appendix 5: Efficacy of Pest Management Tools for Control of Disease and Nematode Pests on Coffee in Hawai'i

	Pest					
Management Tool:	**Cercospora leaf spot, berry blotch, anthracnose**	**Damping off**	**Root-knot nematodes**	**Root rot (*Pythium* spp.)**	**Basal stem rot**	**Comments**
Registered Materials						
Fungicides						
Clarified hydrophobic neem oil (Trilogy)	**P - F**	**P**	**-**	**-**	**-**	
Copper hydroxide (Champ, Kocide, Nu-Cop)	**G**	**-**	**-**	**-**	**-**	Kills the beneficial white halo fungus.
Phosphorous acid salts (Fosphite, Fungi-Phite, Rampart)	**-**	**+**	**-**	**G**	**-**	Only good for *Pythium* and *Phytophthora*.
Tetraamine copper (2+) (Liqui-Cop)	**G**	**P**	**P**	**-**	**-**	
Nematicides						
Azadirachtin (Agroneem Plus, Ecozin 3% EC)	**-**	**-**	**P**	**-**	**-**	
Metam-sodium (Vapam)	**-**	**G**	**G**	**?**	**-**	Preplant only.
1,3-dichlopropene (Telone II)	**-**	**P**	**E**	**-**	**-**	Preplant only.

	Pest					
Management Tool:	**Cercospora leaf spot, berry blotch, anthracnose**	**Damping off**	**Root-knot nematodes**	**Root rot (*Pythium* spp.)**	**Basal stem rot**	**Comments**
Potential pest management tools						
Identification of resistant rootstocks	-	-	E	-	-	Ongoing research.
Paecilomyces lilacinus (Melocon)	-	-	+	-	-	Positive results in pineapple.
Cultural/Nonchemical Controls						
Fallowing with nemastatic cover crop	-	-	F	-	-	
Fertilization	F - G	P	F	-	-	Trees with insufficient nutrients more susceptible to *Cercospora*.
Field location	?	-	E	-	-	
Field/nursery sanitation	F	E	-	-	-	
Green manures	-	F	F	-	-	
Hydroponically-grown seedlings	-	G	?	-	-	
Improving aeration	F	F	-	-	-	

	Pest					
Management Tool:	**Cercospora leaf spot, berry blotch, anthracnose**	**Damping off**	**Root-knot nematodes**	**Root rot (*Pythium* spp.)**	**Basal stem rot**	**Comments**
Cultural/Nonchemical Controls (cont.)						
Irrigation with pathogen-free water	**-**	**E**	**-**	**-**	**-**	
Plant health	**G**	**P - G**	**F**	**-**	**-**	
Potting media selection/handling	**P**	**F - G**	**F**	**-**	**-**	
Sterile or soil-less potting media	**P**	**F - E**	**E (see comment)**	**-**	**-**	Excellent nematode control while in nursery.
Resistant rootstock	**-**	**-**	**E**	**-**	**-**	
Shade	**F**	**-**	**-**	**-**	**-**	
Soil health (complex, healthy, balanced)	**P**	**E if using sanitized media**	**P-F**	**-**	**-**	
Sampling for pathogens for monitoring	**-**	**G**	**E**	**-**	**-**	
Weed host removal	**-**	**-**	**F**	**-**	**-**	
Avoiding herbicide injury	**F - G**	**-**	**P**	**-**	**-**	Injured plants more susceptible to *Cercospora.*

	Pest					
Management Tool:	**Cercospora leaf spot, berry blotch, anthracnose**	**Damping off**	**Root-knot nematodes**	**Root rot (*Pythium* spp.)**	**Basal stem rot**	**Comments**
Cultural/Nonchemical Controls (cont.)						
Composting, organic matter	**F - G**	**-**	**P - F**	**-**	**-**	
Foliar feeding	**F - G**	**-**	**P**	**-**	**-**	
Good nursery practices	**G**	**G**	**G - E**	**-**	**-**	
Good plant nutrition	**F - G**	**-**	**P**	**-**	**-**	
Growing under shade	**G**	**-**	**P**	**-**	**-**	
Intercropping	**F - G**	**-**	**-**	**-**	**-**	Less overbearing dieback.
Minimizing plant stress	**F - G**	**-**	**P**	**-**	**-**	
On-time harvest	**G**	**-**	**-**	**-**	**-**	
Good air circulation/plant spacing	**F - G**	**-**	**-**	**-**	**-**	
Scouting/monitoring	**F - G**	**-**	**P**	**-**	**-**	Effective against nematodes at preplant.
Site selection	**F - G**	**-**	**G - E**	**-**	**-**	
Plants from seed in nursery	**-**	**-**	**G - E**	**-**	**-**	
Variety selection	**-**	**-**	**G - E**	**-**	**-**	

	Pest					
Management Tool:	**Cercospora leaf spot, berry blotch, anthracnose**	**Damping off**	**Root-knot nematodes**	**Root rot (*Pythium* spp.)**	**Basal stem rot**	**Comments**
Cultural/Nonchemical Controls (cont.)						
Irrigation management	-	-	P	E	E	
Avoiding planting too deep	-	-	-	-	E	

Efficacy Rating Scale: E = excellent (90–100% control); G = good (80–90% control),
F = fair (70–80% control); P = poor (<70% control);
? = no data, more research needed; - = not applicable or not used;
+ = no data, but successful on other related organisms; * = not enough experience to rate.

Appendix 6: Efficacy of Pest Management Tools for Control of Weed Pests in Coffee in Hawai'i

	Pest					
	Grasses	**Broadleaves**	**Morningglory**	**Maunaloa *(Canavalia cathartica)***	**Ivy gourd**	**Comments**
Registered Materials						
Pre-emergence:						
Oxyfluorfen (Goal, Goaltender)	**G-E**	**G-E**	**G-F**	**P**	**P**	Especially good against Guinea grass. Weak on large-seeded broadleaves. Weak on sedges. Some weeds may be developing resistance.
Postemergence:						
Carfentrazone (Aim)	*	**G (smaller weeds)**	*	*	*	Fair to poor control of weeds more than 2 to 3 inches tall.
Fluazifop-P-butyl (Fusilade)	**G-E**	-	-	-	-	Thorough coverage required. Grasses must be actively growing.

	Pest					
	Grasses	**Broadleaves**	**Morningglory**	**Maunaloa *(Canavalia cathartica)***	**Ivy gourd**	**Comments**
Postemergence (cont.):						
Glyphosate (Roundup, Buccaneer, Clear-Out, Credit, Durango, Gly-Flo, Glyfos, Glyphomax, Helosate, Honcho, Killzall, Mad Dog, Mirage, Makaze, Rascal, Supersate, Touchdown, Wise Up)	**E**	**G**	**G-F**	**P**	**P**	Must be applied to actively growing weeds. Generic products variable in efficacy.
Nonanoic acid (pelargonic acid) (Scythe)	**P**	**F (seedlings)**	**F (2–3 leaf stage)**	**-**	**-**	
Oxyfluorfen (Goal, Goaltender)	**-**	**F**	**G**	**-**	**-**	Weak on sedges. Some weeds may be developing resistance.
Paraquat dichloride (Gramoxone)	**G (young seedlings)**	**G (smaller weeds)**	**P**	**-**	**-**	
Potential Pest Management Tools						
Pre-emergence:						
Pendimethalin (Prowl)	**E**	**?**	**?**	**?**	**?**	The primary grass pre-emergence herbicide for sugarcane in Hawai'i. Expected to be safe for coffee, because it has little or no postemergence activity. Some effectiveness against some broadleaves.

	Pest					
	Grasses	**Broadleaves**	**Morningglory**	**Maunaloa *(Canavalia cathartica)***	**Ivy gourd**	**Comments**
Postemergence:						
Oxyfluorfen (Goal) over-the-top of plants for morningglory control	**-**	**-**	**G**	**-**	**-**	
2,4-D	**-**	**?**	**?**	**?**	**?**	
Cultural/Nonchemical Controls						
Cover crops	**F**	**G**	**P - G**	**P**	**P**	Some cover crops can efficiently compete.
Flaming	**F**	**G**	**P**	**P**	**P**	Good and fair for annual grasses and broadleaves only.
Grazing animals	**G**	**G**	**?**	**G**	**?**	
Green manures/mulching	**?**	**?**	**?**	**?**	**?**	
Hand pulling	**E**	**E**	**E**	**E**	**E**	
Irrigation method	**P**	**P**	**P**	**P**	**P**	
Mechanical cultivation of inter-rows	**P**	**F**	**P**	**P**	**P**	
Mowing	**P**	**P**	**P**	**P**	**P**	

Efficacy Rating Scale: E = excellent (90–100% control); G = good (80–90% control);
F = fair (70–80% control); P = poor (<70% control);
? = no data, more research needed; - = not applicable or not used;
+ = no data, but successful on other related organisms; * = not enough experience to rate.